

Attachment #2

Bibliography of 198 References Not Included in the Alaska Region EFH DEIS (Abstracts included if available)

The following citation list includes 198 scientific articles that were not included in the Alaska Region Essential Fish Habitat Draft Environmental Impact Statement (EFH DEIS). None of the references in this review were included in the EFH DEIS, with exception of three studies that had key results that were not incorporated in the conclusions of the EFH DEIS (Bradstock and Gordon 1983; Probert et al. 1997; Risk et al. 2002). This comprehensive literature review represents the best available science relevant to the analyses and conclusions in the EFH DEIS. This list includes articles directly related to the effects of bottom trawling and dredging on the sea floor, the effects of trawl closures, fish habitat linkages, and methods to determine EFH. The Fisheries Services' failure to consider this body of work and incorporate its findings into the DEIS constitutes a failure to use the best available science when conducting analyses and drawing conclusions in the EFH DEIS.

Andrews, A. H., L. A. Kerr, G. M. Cailliet and K. H. Coale (2003). Determining the age and growth of three species of deep-sea coral from the Davidson Seamount off Central California. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Ardizzone, G. D. and P. Pelusi (1983). "Regression of a Tyrrhenian *Posidonia oceanica* prairie exposed to nearshore trawling." *Rapports et Proces-Verbaux des Reunions Conseil International pour l'Exploration Scientifique de la Mer Mediterranee*. 28(3): 175-177.

During a series of observations led in the Tyrrhenian Sea, in order to evaluate the effects of the trawling practiced illegally within three miles from the coast, the state of a 'herier' of *Posidonia* subject to this activity has been studied. The results showed a serious situation of alteration, with a regression of the lower limit and a reduction of the density until less than 50 beams/m² for most of the observed zone.

Ardizzone, G. D., P. Tucci, A. Somaschini and A. Belluscio (2000). Is bottom trawling partly responsible for the regression of *Posidonia oceanica* meadows in the Mediterranean Sea? Effects of fishing on non-target species and habitats: biological, conservation and socioeconomic issues. M. J. K. a. S. J. d. G. (eds.). Oxford, UK., Blackwell Science Ltd.: 37-46.

Summary [author's summary]: 1) The seagrass *Posidonia oceanica* is a marine angiosperm that is undergoing regression along Mediterranean coasts. Research in the last few years has demonstrated two possible main sources of damage: anthropogenic modification of sediment characteristics and the physical impacts of fishing gear. Trawl fisheries are considered to be one of the major factors leading to the deterioration of seagrass meadows. The aim of this study was to determine the physical and biological parameters that can be used to identify the reason for regression in different *Posidonia* meadows. 2) A total of 103 stations were sampled in two different areas in the Central Tyrrhenian Sea. The seagrass

meadows in both areas are undergoing regression. The first area is strongly influenced by sedimentation and is untrawlable because of the presence of a hard and irregular seabed. In the second areas, illegal trawling is known to have occurred for almost 20 years. 3) Regression analysis of environmental parameters on seagrass shoot density revealed that, in the untrawled area, the density of seagrass shoots is inversely proportional to the silt and clay content of the sediment, but independent of the depth gradient within the study area. At the same time, the percentage of dead 'matte' (a mat of dead seagrass roots and rhizomes) increases with higher proportions of silt and clay. This suggests that elevated levels of fine sediment may be one cause of the regression of *Posidonia*. Levels of silt and clay that exceed 10% of the sediment composition will cause a decline in seagrass bed. No relationship between sediment characteristics and meadow regression was found in the area that is trawled illegally. Thus, we conclude that fishing activities are the main cause of seagrass regression in this area. 4) While it is difficult to identify the possible sources of fine sediment inundation and thus ameliorate its effects on seagrass beds, illegal trawling can be controlled more readily through physical protection of the seabed using protective reefs or artificial seabed obstacles.

Armstrong, D. A., T. C. Wainwright, G. C. Jensen, P. A. Dinnel and H. B. Andersen (1993). "Taking refuge from bycatch issues: Red king crab (*Paralithodes camtschaticus*) and trawl fisheries in the eastern Bering Sea." *Canadian Journal of Fisheries and Aquatic Sciences* v.50(no.9): p.1993-2000.

Concerns about possibly heavy impacts of bottom trawl fisheries on red king crab (*Paralithodes camtschaticus*) pot fisheries in the eastern Bering Sea led in 1987 to an emergency closure of trawling in an area of adult and juvenile crab habitat. We examine the effectiveness of this bycatch refuge in protecting and possibly enhancing the crab resource using three approaches. First, bycatch of crab in trawl fisheries is a small proportion of total estimated abundance throughout the southeastern Bering Sea but may be high relative to stock abundance within the closed area and relative to annual crab landings; recent regulations have diminished this apparent effect. Effects of direct bycatch on the stock are obscured by lack of evidence on indirect effects of trawling, including crushing of crab and degradation of juvenile habitat. Second, surveys inside and outside the refuge before and after closure show no significant changes in abundance of female and prerecruit male crab. Third, important breeding and hatching grounds and juvenile habitat are not protected by the refuge, leaving long-term stock renewal subject to trawl impacts. We suggest that full consideration of the needs of all life history stages could lead to a more effective refuge design.

Arntz, A. B., H. F. Moore and W. C. Kendall (1994). Mid-and long-term effects of bottom trawling on the benthic fauna of the German Bight. Environmental impact of bottom gear on benthic fauna in relation to natural resources management and protection of the North Sea. S. J. a. L. de Groot, H.J. (eds.). Texel, The Netherlands, NIOZ Rapport

1994-11: 59-74.

Within the framework of the "Impact"-project, the Alfred-Wegener Institute for Polar and Marine Research in Bremerhaven (AWI) has carried out research on the persistent (mid-and long-term) effects of heavy bottom trawling on macrozoobenthos communities and populations in the German Bight. This research is closely related to long-term studies, initiated 25 years ago, of the variability and possible trends apparent in the North Sea macrozoobenthos. Two contrasting study areas were selected in the German Bight: An area around the wreck of the "West Gamma" platform 60 nm northwest of Helgoland, which is enclosed by 4 buoys and accordingly regarded as protected from heavy fishing for 3 years; the "IMPACT-box" 20 nm west of Helgoland, where the fauna of a strongly fished area is being studied over a long time scale and compared with the fauna of neighbouring areas that are less heavily fished. The macrozoobenthos of these areas has been investigated by drag and small dredge sampling. To increase the effects of bottom gears, the "IMPACT-box" was heavily fished by the German research vessels "Solea" and "Victor Hensen", and the Dutch RV "Tridens". The "IMPACT-box" fauna appears to be very homogeneous, belonging to the *Amphiura*-filliformis-association (poor variant, about 110 species). Conversely, the macrozoobenthos is less homogeneous in the "West Gamma" area, mainly due to an overall gradient in the composition of the *Tellina*-fabula-association of the region. It is not yet possible to finally conclude whether the relative richness of this fauna (more than 150 species) is related to the reduced fishing gear stress around the wreck, because of the short duration of this experiment. The finding that some delicate, sensitive species were more abundant inside than outside the wreck area seem to indicate first changes. In addition to the long-term investigations, studies of changes in the diet of demersal fish in the "IMPACT-box" before, during and after fishing have been performed. These studies indicate some changes in the availability of food items and in the feeding behaviour of the predators, which might also contribute to faunal changes.

Aschan, M. M. (1991). "Effects of Iceland scallop dredging on benthic communities in the Northeast Atlantic." ICES Benthos Ecology Working Group, Special International Workshop on the Effects of Physical Disturbance of the Seafloor on Benthic and Epibenthic Ecosystems. Bedford Institute of Oceanography.: 10 p.

In this paper the effects of dredging on the macrobenthos of *Chlamys islandica* fields will be presented. The study was conducted from the research vessel R/V Johan Ruud during the summers 1987-1990 in an area south of Jan Mayen at 60-120m depth and at the northern side of Spitsbergen at 25-80 m depth. Data on the faunal composition was collected by dredging, photography and underwater video recording. In addition to *Chlamys islandica* the dominating species are *Stongylicentrotus droebachiesis*, *Ophiopholis aculeata*, *Ophiura robusta* and *Astarte* sp. At Jan Mayen both the sea cucumber *Cucumaria frondosa* and the crustaceans *Sabinea septemcarinatus* and *Spirontocaris spinus* are common. In the Svalbard areas, the crustaceans *Hyas coarctatus*, *Sclerocrangon boreas*, *Lebbeus polaris* and *Balanus* which encrusts the scallops are characteristic. As a result of

the scallop dredging the number of species, the number of individuals/sample and the biomass in each sample, diminished from 1987 to 1990 in the Moffen areas (N Svalbard). *Strongylocentrotus droebachiensis* and *Pagurus pubescens* became more dominant during the four years of heavy dredging, because they probably stand the physical disturbance better than other species. In the Jan Mayen area no recovery could be observed two years after the fishery stopped. However, *Ophiura robusta* and polychaetes showed an increase.

Ault, J., J. Serafy, D. DiResta and J. Dandelski (1997). "Impacts of commercial fishing on key habitats within Biscayne National Park." Annual Report. Cooperative Agreement No. CA-5250-6-9018: iii + 80 p.

Recreational and commercial harvesting of fishes and invertebrates is permitted in Biscayne National Park (BNP). While there are obvious economic and social benefits associated with fishing in BNP, there may also be insidious effects that reduce ecosystem productivity. Specifically, these effects are in the form of habitat modification and degradation resulting from the use of certain fishing gears. The purpose of the present study was to determine the extent of the effects of commercial activities which predominate in terms of both human participation and areal coverage, namely, bait shrimp trawling and trapping of spiny lobster, stone crab, and blue crab. This project was composed of three principal components: (1) analysis of existing data; (2) field surveys and ground-truthing; and (3) field experiments. Techniques in scientific data visualization and advanced statistical analysis were used to facilitate assessment and modeling. The major activities and findings of our research program are summarized below. 1. Existing data, reports and literature were compiled and analyzed to provide syntheses of the historical development, landings and effort, and current gear and practices for each fishery. 2. Spatially-explicit databases pertaining to submerged natural habitats within BNP and adjacent areas of Biscayne Bay were obtained, integrated, and analyzed. The areal extent of each of BNP's five major benthic communities (i.e., seagrass, hardbottom, mixed seagrass/hardbottom, bare bottom, and offshore coral reef) were quantified and mapped. 3. Questionnaires were designed and distributed to commercial trap and trawl fishermen to characterize temporal and spatial fishing effort patterns. About 25% of the bait shrimp trawlers responded. No questionnaires were returned from lobster, stone crab or blue crab fishermen. Bait shrimp trawlers operating within BNP fish areas measuring about 165 km² during the wet season (June-November) and 350 km² during the dry season (December-May). These areas represent about 24.6% and 52.2% of BNP's entire submerged substrate, respectively. Seagrass habitats are the primary habitats trawled, followed by mixed seagrass/hardbottom, and then hardbottoms. 4. A series of aerial overflights were conducted to estimate the location and numbers of commercial traps from their surface buoys within BNP. Traps were then inspected using SCUBA and snorkeling techniques to characterize the immediate microhabitat upon which the respective traps were set. Trap "footprints" were also captured on video tape. Lobster and stone crab traps were found primarily over *Thalassia* beds, while blue crab traps were found primarily

over *Halodule* beds. 5. Controlled trawling experiments were conducted over seagrass and hardbottom communities. Pre-trawl underwater video recordings were compared with post-trawl recordings of five linear transects that had received from one to five rollerframe trawl passes. While we were unable to detect any damage along the seagrass bed transects, damage to sessile invertebrates along the hardbottom transects was conspicuous after one pass. The rate of damage appeared to decrease with subsequent trawling efforts. The sponge *Ircina felix* and the corals of the genus *Pseudoplexaura* appeared to be the taxa most vulnerable to breakage or dislodgement by trawling. 6. Trap experiments revealed that damage to underlying seagrasses depended on soak time, trap type and plant species. For lobster traps, mean *Thalassia* loss was approximately 1% of initial plant cover after one day, 7% after one week, and 26% after one month. For stone crab traps mean loss of *Thalassia* cover was 4% after one day, 27% after one week, and 74% after one month. Blue crab traps reduced *Halodule* coverage by 4% after one day, by 24% after one week and by 70% after one month. 7. The bait shrimp fishery regularly comes in contact with a largest contiguous areas of BNP's submerged habitat resources. Restriction of commercial bait shrimp fishing in BNP's seagrass habitats cannot be justified solely on the basis of physical habitat damage. However, the issue of juvenile fish and crab bycatch deserves further attention, if not directed research. 8. While rollerframe trawling does not appear to damage seagrasses, damage to sessile invertebrates (i.e., sponges and soft corals) in hardbottom communities is conspicuous and is likely to be long-lasting. Hardbottom habitats would undoubtedly benefit from closure of commercial bait shrimping in areas that support high densities of sponges and corals. The feasibility of accurately marking the boundaries of BNP's hardbottom areas and preventing nocturnal trawling within them should be investigated. 9. It is essential to conduct a limited number of additional trawl effects experiments in conjunction with areal closures to obtain precise estimates of habitat recovery rates for sponge and soft-coral habitats damaged by commercial trawling activities. 10. The primary benthic resource that the three major trap fisheries affect is seagrass habitat. The extent of damage to the habitat is a function of gear soak time, trap type, and the particular seagrass species which constitute the habitat. We strongly recommend that additional field experiments be conducted which focus on the rate at which *Thalassia* and *Halodule* recolonize after being impacted by trap-damage. 11. We further recommend that additional measurements of size and spatio-temporal extent of each of the trap fisheries be conducted. These studies are required before definitive estimates of cumulative Park-wide resource damage resulting from commercial trap fishing can be made.

Auster, P. (2001a). "North American Journal of Fisheries Management ; February 2001; v.21, no.1, p.1-9." North American Journal of Fisheries Management v.21(no.1): p.1-9.

The use of precautionary management actions within a fisheries context has generally been limited to reducing fishing mortality. By the use of quantitative models, overfishing thresholds can be determined and actions can be taken to reduce the probability of further population declines and to allow rebuilding.

Within this context, four management approaches have been defined (i.e., preventive approach, corrective approach, precautionary approach, and precautionary principle) on the basis of levels of uncertainty in the information used to make decisions and the potential cost of errors as a result of those decisions. In this paper, I apply these approaches to developing a precautionary and adaptive habitat management framework. Fishing effort metrics are used to develop estimates of the area of seafloor impacted by fishing, and thresholds are proposed to trigger specific types of management actions. Information needs include the cumulative area impacted by all gears, the distribution of habitats and diversity of key taxa, effects of gears on habitat and patterns of diversity, and linkages between habitat and the dynamics of exploited populations. Incentives for the fishing industry that will improve the information available to make decisions and reduce the level of precaution required for managing exploitation of wild populations are discussed. This framework is a starting point for management agencies to develop precautionary and adaptive habitat management programs that promote both the sustainability of exploited populations and the maintenance of biological diversity.

Auster, P. J. (1998). "A conceptual model of the impacts of fishing gear on the integrity of fish habitats." *Conservation Biology* v.12(no.6): p.1198-1203.

Fishing gear is used over large regions of continental shelves worldwide, but studies of the effects of fishing on seafloor habitats are generally conducted on a limited number of sediment types, making the wider application of particular studies difficult. Fishing gear can reduce habitat complexity by smoothing bedforms, removing emergent epifauna, and removing species that produce structures such as burrows. I developed a conceptual model of gear impacts across gradients of habitat complexity and levels of fishing effort to provide a more holistic understanding of the effects of fishing gear. Each habitat type, in an unaffected state, was categorized and scored numerically based on the components of habitat structure. Values for highly affected habitats, based on observations, were integrated into the model and represented the most affected state. The model predicts linear reductions in complexity based on linear increases in fishing effort. For example, the complexity value of pebble-cobble with emergent epifauna decreases linearly to half the unaffected value (i.e., 10 to 5) in the most affected condition. Research is needed to refine the model and develop improved predictive capabilities. For example, threshold effects may occur that depend on habitat type, fishing gear, and fishing effort. Adding feedback loops to the model, based on recovery rates of habitats, will greatly increase the value of such models to managers. The model can be used directly for management in the current iteration by adopting a well-conceived adaptive management strategy. The objective of such an approach must include both the sustainable harvest of fishes and the maintenance of biodiversity.

Auster, P. J., K. Joy and P. C. Valentine (2001b). "Fish species and community

distributions as proxies for seafloor habitat distributions: The Stellwagen Bank National Marine Sanctuary example (Northwest Atlantic, Gulf of Maine)." *Environmental Biology of Fishes* v.60(no.4): p.331-346.

Defining the habitats of fishes and associated fauna on outer continental shelves is problematic given the paucity of data on the actual types and distributions of seafloor habitats. However many regions have good data on the distributions of fishes from resource surveys or catch statistics because of the economic importance of the fisheries. Fish distribution data (species or communities) have been used as a proxy for the distribution of habitats to develop precautionary conservation strategies for habitat protection (e.g., marine protected areas, fishing gear restrictions). In this study we assessed the relationships between the distributions of fish communities and species derived from trawl survey data with the spatial distribution of sediment types determined by sampling and acoustic reflectance derived from multibeam sonar surveys in Stellwagen Bank National Marine Sanctuary. Fish communities were correlated with reflectance values but all communities did not occur in unique sediment types. This suggests that use of community distributions as proxies for habitats should include the caveat that a greater number of communities within an area could indicate a greater range of habitat types. Single species distributions showed relationships between abundance and reflectance values. Trawl catches with low abundances had wide variations in reflectance values while those with high abundances had narrower ranges indicating habitat affinities. Significant non-random frequency-dependent relationships were observed for 17 of 20 species although only 12 of 20 species had significant relationships based on rank correlation. These results suggest that species distributions based on trawl survey data can be used as proxies for the distribution of seafloor habitats. Species with known habitat associations can be used to infer habitat requirements of co-occurring species and can be used to identify a range of habitat types.

Bailey, K., E. Brown and J. Duffy-Anderson (2003). "Aspects of distribution, transport and recruitment of Alaska plaice (*Pleuronectes quadrituberculatus*) in the Gulf of Alaska and eastern Bering Sea: comparison of marginal and central populations." *JOURNAL OF SEA RESEARCH* 50(2-3): 87-95.

Shelikof Strait in the Gulf of Alaska appears to be near the extreme warm southern end of the spawning range of Alaska plaice (*Pleuronectes quadrituberculatus*). The spawning location, larval transport, and retention in the nursery area are documented from analysis of historical ichthyoplankton surveys of the region. Data from juvenile and adult trawl surveys were analysed to characterise the nursery areas. Aspects of the spawning distribution, population dynamics and juvenile nursery habitat characteristics in the Gulf of Alaska were compared with those in the primary area of its distribution in the eastern Bering Sea. In the Gulf of Alaska, concentrated spawning appears to be localised on the narrow shelf between 50 to 100 m depth on the north flank of the Shelikof Strait Sea Valley and in several other areas. Larvae drift downstream with prevailing currents. Most juveniles are located in water less than 50 m deep over a mud or

sand bottom. Over its range, the mean biomass of plaice is related to the amount of suitable juvenile nursery bottom habitat. The abundance of the marginal Gulf of Alaska population is more variable than the main stock of the eastern Bering Sea. Because the continental shelf in the Gulf of Alaska is narrow and suitable habitat is fragmented, it is proposed that the population of Alaska plaice in the Gulf of Alaska is limited by recruitment to suitable nursery habitat, and that there is a dynamic interplay between the landscape ecology and larval drift due to highly variable currents.

Bailey, K. M. (1981). "Larval transport and recruitment of Pacific hake, *Merluccius productus*." Marine Ecology Progress Series v.6(no.1): p.1-10.

The advection of *M. productus* larvae offshore appears to be a significant factor in establishing recruitment levels. Pacific hake spawn mostly in Jan. and Feb. over the continental slope in the area of study. The offshore distribution of larvae is positively correlated to offshore Ekman transport, while year class strength and offshore Ekman transport at the time of spawning are negatively correlated. Since the juvenile nursery is inshore over the continental shelf, larvae advected seaward of the continental shelf probably have poor survival as juveniles. Larval survival also appears to be poor in cold years of strong offshore transport. A multiple regression model accounts for 72% of the variance in an index of year class strength.

Bartsch, J., K. Brander, M. Heath, P. Munk, K. Richardson and E. Svendsen (1989). "Modelling the advection of herring larvae in the North Sea." Nature (London) v.340(no.6235): p.632-636.

Bavestrello, G., C. Cerrano, D. Zanzi and R. Cattaneo-Vietti (1997). "Damage by fishing activities in the Gorgonian coral *Paramuricea clavata* in the Ligurian Sea." AQUATIC CONSERVATION-MARINE AND FRESHWATER ECOSYSTEMS 7(3): 253-262.

1. The analysis, by means of line transects, of a *Paramuricea clavata* (Anthozoa: Gorgonacea) population forming a facies of the Mediterranean coralligenous community along the Portofino Promontory (Ligurian Sea, Italy) evidenced a high per cent of lesions inflicted to the gorgonian coenenchyme by anchoring and fishing activities. 2. This damage favours the development of aggregates of epibionts (mainly hydroids and bryozoans) which leads to greater mechanical stress through increased resistance of the colonies to water movement; when polychaetes and nematodes colonize the denuded skeleton, their burrowing activity weakens the colony. 3. In situ tissue regeneration experiments suggested that aggregation of epibionts can develop only if the injuries result, from continuing abrasion. 4. Injuries caused by anchoring and fishing can therefore be considered the major cause of mortality of *Paramuricea clavata* in the Portofino Promontory. 5. *Paramuricea clavata* re-colonizes experimentally denuded areas slowly and colonies take many years to reach the size of existing individuals and

can be damaged easily by fishing and anchoring. 6. Special protection is needed for this key species of Mediterranean coral at Portofino Promontory, which is proposed as a Natural Marine Park.

Beaulieu, S. (2001). "Life on glass houses: sponge stalk communities in the deep sea." *MARINE BIOLOGY* 138(4): 803-817.

Photographs of the deep-sea floor often show organisms attached to biogenic structures that protrude from the soft bottom. In particular, the stalks of glass sponges (hexactinellids) provide hard substrata and act as habitat islands for deep-sea fauna. The primary objectives of this study were to determine the abundance of glass sponge "stalks" at an abyssal station in the NE Pacific, to identify the fauna associated with stalks, and to compare the distribution patterns of epifaunal taxa both horizontally and vertically. Densities of stalks and large epifauna were estimated from analysis of similar to 9 km of photographic transects taken in 1994-1995 at station hi (34 degrees 45'N; 123 degrees 00'W; 4,100 m depth) off California, USA. At least 87% of the stalks were the spicule columns of live or dead hexactinellids in the genus *Hyalonema* (Gray, 1832). Stalks appeared to be distributed randomly across the sea floor (density: 0.13 stalks m⁻²). A colonial zoanthid, *Epizoanthus stellaris* (Hertwig, 1888), inhabited 20% of the stalks and was the most commonly observed epifaunal organism, followed by other suspension feeders that generally were situated at the top of the structures. Thirty-five stalk communities were collected in tube cores in 1994-1995 using the submersible "Alvin". A total of 139 taxa was associated with these hard-substratum habitats (another five species were observed only in photographs). Although taxon richness was high, the species diversity of these communities was relatively low due to the dominance in percentage abundance of a foraminiferan, *Cibicides lobatulus* (Walker and Jakob, 1798), and a serpulid polychaete, *Bathypervermilia* sp. (Zibrowius, 1973). The relationship between number of taxa and surface area of the stalks yielded a slope (z-value) typical of islands with a low rate of immigration. Three-dimensional complexity created by branching epifauna on the stalks provided more surface area and a variety of cryptic microhabitats. Vertical zonation on the stalks appeared to be controlled by biological interactions among species, with solitary fauna and certain functional groups of colonial organisms restricted by sheetlike colonial organisms that appeared to be dominant space competitors.

Beck, M. (1995). "Size-specific shelter limitation in stone crabs: A test of the demographic bottleneck hypothesis." *Ecology* (Washington D C) v.76(no.3): p.968-980.

Habitat structural complexity can facilitate species persistence by providing refuges and the availability of refuges may control the size of many populations. In organisms that increase greatly in size during ontogeny the size and abundance of refuges is particularly important, because population-regulating factors may operate strongly on only one size class or ontogenetic stage within a population, creating a demographic bottleneck. I test the demographic bottleneck hypothesis

in stone crabs by first supplementing shelter with five different sizes of polyvinyl chloride (PVC) pipe at eight sites in St. Joseph Bay, Florida to determine the size class most likely to be shelter limited. I then used tethering experiments, cage studies, and natural observations to ask if habitat structural complexity regulates the stone crab population through its size-specific effects on growth, survival, and fecundity. Shelter availability appears to create a demographic bottleneck that affects the growth and fecundity of large crabs. In both 1991 and 1992, the largest PVC pipes were occupied in significantly greater proportions than smaller pipes, suggesting that this shelter size class is limiting. Predation is size specific; smaller individuals are at significant risk but no large crabs were taken by predators. However, shelter is particularly important for the growth of large crabs. There was a fivefold increase in molting individuals on shelter-supplemented sites relative to natural densities suggesting that the bottleneck size class has been identified correctly and that shelter additions can alleviate the bottleneck. Supplemental shelters also particularly attracted gravid females and, in tethering experiments, females with shelter produce egg masses twice as quickly as females without shelter. These results differ from most prior results in marine populations in two ways. First, it is factors affecting adults and not juveniles that may regulate the stone crab populations. Second, refuge use in those size classes likely to be shelter limited is not explained primarily by predation, but by effects on growth and fecundity. The evidence suggests the merits of the demographic bottleneck hypothesis; habitat structural complexity may affect both the size of populations and the size of individuals within the population.

Bizzarro, J. (2002). Final Report: Preliminary Video Analysis of Coral, Sponge, and Metridium Distribution from Rockfish Transects made with the Delta Submersible in Southeast Alaska. Regional Information Report No. 1J02-38, Alaska Department of Fish and Game Subcontract to Moss Landing Marine Laboratories: 23 pages.

Borg, A., L. Pihl and H. Wennhage (1997). "Habitat choice by juvenile cod (*Gadus morhua* L.) on sandy soft bottom with different vegetation types." *Helgoländer Meeresuntersuchungen* v.51(no.2): p.197-212.

Habitat choice by juvenile cod (*Gadus morhua* L.) on sandy bottoms with different vegetation types was studied in laboratory. The experiment was conducted day and night in flow-through tanks on two different size-classes of cod (7-13 and 17-28 cm TL). Four habitats, typical of shallow soft bottoms on the Swedish west coast: *Fucus vesiculosus*, *Zostera marina*, *Cladophora* sp. and bare sand, were set up pair-wise in six combinations. The main difference between habitats in this study was vegetation structure, since all parameters except vegetation type was considered equal for both sides of the experimental tanks and natural prey was eliminated. The results showed a difference in habitat utilization by juvenile cod between day (light) and night (dark). During day time the fishes showed a significant preference for vegetation, while nocturnally no significant choice of habitat was made. Both size-classes preferred *Fucus*, considered the

most complex habitat in this study, when this was available. The smaller size-class seemed to be able to utilize the other vegetation types as well, always preferring vegetation over sand. Larger juvenile cod, on the other hand, appeared to be restricted to *Fucus*. This difference in habitat choice by the two size-classes might be due to a greater dependence on shelter from predation by the smaller juveniles, causing them to associate more strongly with vegetation. The larger juveniles avoided *Cladophora*, since they might have difficulties in entering the compact structure of this filamentous algae. Availability of vegetation at day time, as a predation refuge, as well as of open sandy areas for feeding during night, thus seems to be important for juvenile cod. It is concluded that eutrophication-induced changes in habitat structure, such as increased dominance by filamentous algae, could alter the availability of predation refuges and foraging habitats for juvenile cod.

Boyd, S. and H. Rees (2000). "The effects of dredging intensity on the macrobenthos in commercial aggregate extraction sites in the English Channel." ICES CM 2000 -E:08 - Annex 6.: 15 p.

A survey was designed to examine the nature of impacts on the benthos arising from commercial aggregate extraction at sites east of the Isle of Wight in the English Channel. Samples of sediments and the associated macrofauna were collected from areas subjected to different levels of dredging intensity. Several of the sampled sediments collected from within areas of intensive dredging contained reduced quantities of gravel. However, changes in particle size were not sufficient to account for differences in assemblage structure between areas that had only limited exposure to the direct effects of dredging compared with undredged areas. Samples from intensively dredged sediments differed from undredged sites due to significant reductions ($p < 0.05$) in numbers of species, biomass, species richness and diversity. Intermediate values of all calculated univariate measures were also observed in areas of reduced dredging intensity. Populations of the reef forming polychaete *Sabellaria spinulosa* were found to be particularly susceptible to dredging disturbance. This in contrast to *Balanus* juveniles which were observed to be more numerous in intensively dredged sediments compared with elsewhere, suggesting that some settlement of this taxon occurs even during times of extraction.

Bradshaw, C., L. O. Veale and A. R. Brand (2002). "The effect of scallop-dredge disturbance in long-term changes in Irish Sea benthic communities: a Re-analysis of an historical dataset." *Journal of Sea Research* 47(2): 161-184.

Benthic community data collected between 1938 and 1950 by N.S. Jones were compared with modern samples from seven sites in the Irish Sea. Multivariate and univariate methods were used to compare community change over time and examine the possible impact of scallop dredging over the 60 year time period. A conservative approach to data analysis ensured that observed differences in faunal composition between time periods were not due to differences in sampling

methodologies or taxonomic identification. The community composition changed at all sites, though to different degrees. The amount of change was related to how long a site had been fished, rather than fishing intensity. Mobile, robust and scavenging taxa have increased in abundance, while slow-moving or sessile, fragile taxa have decreased. Differences between historical and modern samples were greater than could be accounted for by the natural variability of the system (as indicated by spatial and temporal replication at three sites) and indicate real long-term change. This study emphasizes that, in the absence of good-quality data series and experiments, the use of 'fuzzy' historical data is often the only possible way to judge long-term change and can yield valuable results.

Bradstock, M. and D. P. Gordon (1983). "Coral-like bryozoan growths in Tasman Bay, and their protection to conserve local fish stocks." *New Zealand Journal of Marine and Freshwater Research* 17: 159-163.

Mounds of "coral" off Separation Point, Tasman Bay, which have recently been protected to conserve ecologically associated commercial fish species, are predominantly growths of Bryozoa. Two species (*Celleporaria agglutinans*, *Hippomenella vellicata*) make up the bulk of these structures. Trawling through the "coral" grounds has affected the fish populations to the extent that an area has been closed to trawling to conserve stocks.

Buhl-Mortensen, L. and P. Mortensen (2004). "Crustaceans associated with the deep-water gorgonian corals *Paragorgia arborea* (L., 1758) and *Primnoa resedaeformis* (Gunn., 1763)." *JOURNAL OF NATURAL HISTORY* 38(10): 1233-1247.

To explore the crustacean fauna associated with deep-water gorgonian corals, suction samples were taken from colonies of *Paragorgia arborea* and *Primnoa resedaeformis* using a Remotely Operated Vehicle. Seven colonies of *P. arborea* and eight of *P. resedaeformis* were sampled from 330-500m depth in the Northeast Channel off Nova Scotia. A total of 17 species were identified as being associated with the corals. The *P. arborea* fauna was richer than the *P. resedaeformis* fauna in both abundance and number of species, with 1303 versus 102 individuals and 16 versus seven species, respectively. However, 13 of the species associated with *P. arborea* were from hydroids attached to the coral. Amphipods dominated the fauna both in abundance and numbers of species and the most common species were *Metopa bruzelii*, *Stenopleustes malmgreni*, *Proboloides calcarata* and *Aeginella spinosa*. The isopod *Munna boeckii* and the cirripede *Ornatoscalpellum stroemii* were also quite common. The most strongly associated crustaceans were two parasitic poecilostomatid copepods; these are common also on tropical gorgonians and are most likely obligate associates. The frequently occurring shrimp *Pandalus propinquus* probably avoids predation by seeking protection among the coral branches. Shrimp counts from video records showed that visual inspection without physically disturbing colonies will generally not reveal the crustaceans hidden in coral colonies. The galatheid *Eumunida picta* was observed on *P. resedaeformis* colonies. The fauna of the

deep-water gorgonians corresponded to the fauna of tropical shallow-water gorgonians in the numerical dominance of amphipods and parasitic copepods; however, species richness is higher and decapods, which constitute a rich fauna on tropical gorgonians, were only represented by two species.

Buhl-Mortensen, L. and P. B. Mortensen (2003). Distribution and diversity of species associated with deep-sea gorgonian corals off Atlantic Canada. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Carr, H. A. and H. O. Milliken (1998). Conservation engineering: options to minimize fishing's impacts to the sea floor. Effects of fishing gear on the sea floor of New England. MIT Sea Grant Publication 98-4. P.-i. E. M. D. a. J. P. (eds.). Boston, MA.

A paper discussing the technological advances in demersal fishing over the last 20 years, with emphasis on the improvements in trawl gear designs. Different gear designs are discussed, as well as the impacts to the respective habitat types where they are used. Methods to further reduce impacts to habitat by improving gear design, limiting trawling terrain, and changing to fixed gears are suggested.

Carr, M. H. (1991). "Habitat selection and recruitment of an assemblage of temperate zone reef fishes." JOURNAL OF EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY v.146(no.1): p.113-137.

Spatial and temporal patterns of recruitment are described for young-of-year of nine species of rockfish (Scorpaenidae, genus *Sebastes*) in a giant kelp *Macrocystis pyrifera* (L.) C.Ag. forest off central California, USA. Though all nine species recruited during or soon after the months of maximum coastal upwelling, variation in timing of peak recruitment among species corresponded to the sequential parturition of pelagic larvae. Recruits of each rockfish species exhibited strong and significantly distinct habitat selection based on substratum type and relief, algal type, and vertical position in the water column. To determine the effect of habitat structure on the distribution and abundance of recruits, observations of habitat selection were made within an unmanipulated *M. pyrifera* forest and compared to sites where the presence of *M. pyrifera* was altered. Whereas variation in substratum type can contribute to spatial patterns of rockfish recruitment, the temporal dynamics of algal abundance, especially *M. pyrifera*, may strongly influence temporal, as well as spatial variability of rockfish recruitment. These results indicate that the structural composition of a reef, particularly the occurrence of *M. pyrifera*, strongly influences the magnitude and species composition of local recruitment of this rockfish assemblage.

Christensen, L. (1982). Management and Utilization of Mangroves in Asia and the Pacific. Rome, Food and Agricultural Organization of the United Nations.

Christiansen, S. and S. Lutter (2003). Is there any hope for the conservation of cold-water corals in Europe? Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Collie, J. S., G. A. Escanero, L. Hunke and P. C. Valentine (1996). "Scallop dredging on Georges Bank: photographic evaluation of effects on benthic epifauna." ICES C.M. 1996/Mini:9.: 14 p.

Situated off the east coast of North America, the gravel sediment habitat on the northern edge of Georges Bank is an important nursery area for juvenile fish, and the site of a productive scallop (*Pecten maximus*) fishery. On recent cruises to this area, we collected dredge samples and photographs from sites of varying depths and with varying degrees of disturbance from otter trawling and scallop dredging. Colonial epifaunal species were conspicuously less abundant at disturbed sites. These differences were quantified by analyzing of still photographs of the sea bottom. In each photo, the percentages of the bottom covered by bushy, plant-like organisms and colonial worm tubes (*Filograna implexa*) were determined, as were the presence/absence and colors of encrusting bryozoa. Non-colonial organisms were also identified as specifically as possible, and sediment type was quantified. Significant differences between dredged and undredged areas were found for all variables tested except presence/absence of encrusting bryozoa. Emergent colonial epifaunal taxa provide a complex habitat for shrimp, polychaetes, brittle stars and small fish at undredged sites.

Collie, J. S., G. A. Escanero and P. C. Valentine (1997). "Effects of bottom fishing on the benthic megafauna of Georges Bank." Marine Ecology Progress Series 155: 159-172.

This study addresses ongoing concerns over the effects of mobile fishing gear on benthic communities. Using side-scan sonar, bottom photographs and fishing records, we identified a set of disturbed and undisturbed sites on the gravel pavement area of northern Georges Bank in the northwest Atlantic. Replicate samples of the megafauna were collected with a 1 m Naturalists' dredge on 2 cruises in 1994. Compared with the disturbed sites, the undisturbed sites had higher numbers of organisms, biomass, species richness and species diversity; evenness was higher at the disturbed sites. Undisturbed sites were characterized by an abundance of bushy epifaunal taxa (bryozoans, hydroids, worm tubes) that provide a complex habitat for shrimps, polychaetes, brittle stars, mussels and small fish. Disturbed sites were dominated by larger, hard-shelled molluscs, and scavenging crabs and echinoderms. Many of the megafaunal species in our samples have also been identified in stomach contents of demersal fish on Georges Bank; the abundances of at least some of these species were reduced at the disturbed sites.

Collie, J. S. E., Galo A.; Valentine, Page C. (2000). "Photographic evaluation of the

impacts of bottom fishing on benthic epifauna." *ICES Journal of Marine Science* v.57(no.4): p.987-1001.

The gravel sediment habitat on the northern edge of Georges Bank (East coast of North America) is an important nursery area for juvenile fish, and the site of a productive scallop fishery. During two cruises to this area in 1994 we made photographic transects at sites of varying depths that experience varying degrees of disturbance from otter trawling and scallop dredging. Differences between sites were quantified by analyzing videos and still photographs of the sea bottom. Videos were analyzed for sediment types and organism abundance. In the still photos, the percentages of the bottom covered by bushy, plant-like organisms and colonial worm tubes (*Filograna implexa*) were determined, as was the presence/absence of encrusting bryozoa. Non-colonial organisms were also identified as specifically as possible and sediment type was quantified. Significant differences between disturbed and undisturbed areas were found for the variables measured in the still photos; colonial epifaunal species were conspicuously less abundant at disturbed sites. Results from the videos and still photos were generally consistent although less detail was visible in the videos. Emergent colonial epifauna provide a complex habitat for shrimp, polychaetes, brittle stars and small fish at undisturbed sites. Bottom fishing removes this epifauna, thereby reducing the complexity and species diversity of the benthic community.

Conover, D. O., J. Travis and F. C. Coleman (2000). "Essential fish habitat and marine reserves: An introduction to the Second Mote Symposium in Fisheries Ecology." *Bulletin of Marine Science* v.66(no.3): p.527-534.

A call for marine reserves has emerged at the forefront of natural resource policy and management for three reasons. First, reserves can protect critical habitat for fishery resources that have been depleted through overharvesting or habitat destruction. Second, they can help conserve marine diversity. Third, in some circumstances, they might be able to enhance the harvest of stocks outside the reserve. The enthusiasm for marine reserves reflects their fit with five themes that recur in current management theory: the desirability of risk-averse resource management, the practical management of human activity, the necessity for new scientific information, the wisdom of protecting habitat damaged by fishing effort, and the perception that new, immediate measures are needed to help restore our fisheries. This symposium was designed to address several questions surrounding these themes. These include questions about when reserves would work best, the optimal siting of reserves, the role of reserves within broader management schemes, the social issues surrounding the implementation of reserves, and whether reserves can actually perform the roles that fisheries scientists hope they will. There is consensus on some of the answers, but not on all; most critically, how well existing reserves can enhance the stock outside of the reserves remains a subject of intense debate.

Conway, K. W., M. Krautter, J. V. Barrie, F. Whitney, R. E. Thomson, G. Mungov and

M. Bertram (2003). Sponge reefs in the Queen Charlotte Basin, Canada: Oceanographic and geological controls on growth and development. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Cordes, E., J. Nybakken and G. VanDykhuisen (2001). "Reproduction and growth of *Anthomastus ritteri* (Octocorallia : Alcyonacea) from Monterey Bay, California, USA." MARINE BIOLOGY 138(3): 491-501.

Anthomastus ritteri Nutting, 1909 is a deep-sea alcyonacean from the Pacific coast of California, USA, and Baja California, Mexico. Although descriptive studies exist, detailed information on the reproduction and life history of any species of *Anthomastus* or on deep-sea octocorals in general is sparse. Laboratory specimens of *A. ritteri* were studied with respect to their reproductive biology, timing of larval settlement, and growth rates. Collected *A. ritteri* colonies were dioecious larval brooders that exhibited continuous reproduction. Developing larvae were brooded in the siphonozooids, with large colonies capable of containing over 4000 oocytes and larvae. The demersal planula larvae were capable of settlement 2 days after release. The longest competency period recorded in the laboratory was 123 days. A Gompertz growth model was based on the size-specific growth rates of 15 colonies. Growth was slow for the first 1-2 years, but increased when colonies comprised three to four feeding polyps. Growth slowed in adult colonies, approaching an asymptotic size. In the model, *A. ritteri* approached asymptotic size between 25 and 30 years of age. This age is greater than those reported for tropical gorgonian colonies. These results agree with the general notion that growth rates are reduced and longevity increased in deep-sea species.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton and M. van den Belt (1997). "The Value of the World's Ecosystem Services and Natural Capital." *Nature* 387: 253-260.

Costello, M. J., M. McCrea, A. Freiwald, T. Lundalv, L. Jonsson, B. J. Bett, T. van Weering, H. de Haas, J. M. Roberts and D. Allen (2003). Function of deep-sea cold-water *Lophelia* coral freefs as fish habitat in the eastern Atlantic. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Cote, D., S. Moulton, D. A. Scruton and R. S. McKinley (2001). "Microhabitat use of juvenile Atlantic cod in a coastal area of Bonavista Bay, Newfoundland." *Transactions of the American Fisheries Society* v.130(no.6): p.1217-1223.

Scuba surveys were used to examine the seasonal abundance and habitat use (substrate, temperature, and depth) of two species of juvenile cod *Gadus* spp. over the diel cycle in a coastal area of Bonavista Bay, Newfoundland. The abundance of age-0 cod increased throughout the study period (from early August until mid-

November), while that of age-1 and age-2 Atlantic cod *Gadus morhua* peaked in mid-October. The diel abundance of age-1 Atlantic cod increased with the onset of dusk, indicating that these individuals moved from other habitats into the study area at this time. Although all age-classes used areas with kelp significantly more than other areas during the day, the differences between age-classes became apparent at dusk. Age-1 cod showed no significant difference in habitat density at dusk, while age-2 cod had higher concentrations over complex substrates (kelp and boulders); habitat use at dusk by age-0 cod was inconclusive. No significant differences in nocturnal habitat use were found for age-0 and age-1 fish; the results for age-2 fish were inconclusive. Throughout the study period, the 0 and 1 age-classes were found in shallower water at night. Previous studies suggest that diel inshore movements provide metabolic benefits to cod moving through a temperature gradient associated with a distinct thermocline. Although cod occupied colder water during the day in the summer and early fall, the continuation of this diel movement pattern after the disappearance of the thermocline suggests that there are other mechanisms influencing this pattern.

Cote, I. M., D. Vinyoles, J. D. Reynolds, I. Doadrio and A. Perdices (1999). "Potential impacts of gravel extraction on Spanish populations of river blennies *Salaria fluviatilis* (Pisces, Blenniidae)." *Biological Conservation* 87(3): 359-367.

River blennies *Salaria fluviatilis* have a wide circum-Mediterranean distribution, but they are mostly confined to small, very localized populations. In the Iberian Peninsula, they are endangered due to a variety of causes, including gravel extraction. This study identified the breeding requirements of river blennies at a site where gravel extraction takes place and at three other sites in different drainage basins in Spain. Breeding males chose nest stones that were significantly larger than other stones available in the immediate vicinity. Although clutch area was significantly related to stone size in two of three populations, male size was not. Stone size appeared to be the main correlate of clutch size, and stone sizes were significantly smaller at sites where gravel had been extracted. The potential effects of stone and gravel removal on nesting density and egg productivity were simulated, and it was found that a 75% reduction in stone size, as observed in this study, could result in a 47% decrease in nesting density. Because of the relationship between clutch size and nest stone size, egg production would be reduced even further, to 25% of its initial level. Removal of stones and gravel from the river bed also causes structural alterations which may render the habitat unsuitable for breeding blennies despite the presence of apparently suitable nest stones. Our results may be applicable to the conservation of other substrate-spawning fish.

Cranfield, H. J., G. Carbines, K. P. Michael, A. Dunn, D. R. Stotter and D. J. Smith (2001). "Promising signs of regeneration of blue cod and oyster habitat changed by dredging in Foveaux Strait, southern New Zealand." *New Zealand Journal of Marine and Freshwater Research* v.35(no.5): p.897-908.

Epifaunal reefs in Foveaux Strait are oyster (*Ostrea chilensis* Philippi, 1845) habitat. One hundred and thirty years of oyster dredging has diminished the complexity and distribution of these reefs. Commercial densities of blue cod (*Parapercis colias* (Forster in Bloch and Schneider, 1801)) were discovered on epifaunal reef habitat in 1989 and became the focus of a major blue cod fishery. We document habitat changes that followed the closing of the oyster fishery in 1993 and interactions between the blue cod and oyster fisheries after the oyster fishery was reopened in 1996. Evidence from blue cod fishers and oyster surveys suggests that the benthic habitat of some oyster beds regenerated in the absence of dredging and that the relative density of blue cod, and then oysters, rebuilt to commercial levels. Benthic habitat was modified once more when oyster dredging restarted and the relative density of blue cod on oyster beds fell again. The observations suggest that rotational fishing of oysters could mitigate the effects of dredging on habitat and that marine protected areas could expedite habitat recovery. Increasing habitat complexity and blue cod density on a reef of oyster shells formed by an oyster fisher suggests that habitat enhancement might remedy effects of dredging. The questions raised by the observations could be answered by management experiments on the scale of the fisheries.

Cranfield, H. J., K. P. Michael and I. J. Doonan (1999). "Changes in the distribution of epifaunal reefs and oysters during 130 years of dredging for oysters in Foveaux Strait, southern New Zealand." *Aquatic Conservation: Marine and Freshwater Ecosystems* 9(5): 461-484.

Foveaux Strait, a narrow seaway that is exposed to heavy wave action and strong tidal currents, has been the subject of an oyster fishery for over 130 years. Before the oyster fishery commenced the seafloor was extensively covered by epifaunal reefs that were tidally-oriented, linear aggregations of patch reefs. Patch reefs are formed by the bryozoan *Cinctipora elegans* cemented by encrusting bryozoa, ascidians, sponges, and polychaetes. The molluscan epifauna is dominated by the oyster, *Tiostrea chilensis* and bysally attached bivalves. Mortality of oysters is probably lower and recruitment and growth may be higher within the reef habitat. Fishers found commercial densities of oysters occurred only on epifaunal reefs. Fishers exploited local groups of reefs. These groups form the patchily distributed oyster beds characteristic of this fishery. Dredging for oysters progressively modified reefs until oysters were the only epifauna remaining. Dredges caught oysters more efficiently after the catch bag no longer became saturated with other epifauna. This heightened efficiency allowed fishers to rapidly reduce oyster density to commercial extinction. Oyster density has not rebuilt on oyster beds abandoned by fishers. The rate of modification of epifaunal reefs was slower during the early years of the fishery but has accelerated, especially over the last 37 years. Frequency of disturbance increased as the numbers of vessels fishing grew and fishers developed speedier dredging methods. Intensity of disturbance also increased as heavier dredges were introduced and allowed focused fishing of reefs. Oysters became reduced to low densities in the eastern and central areas that fishers then abandoned. The commercially exploited area subsequently

expanded to the limits of Foveaux Strait. With accelerated modification of oyster habitat, disease mortality has become more important. Attempting to rebuild the fishery by oyster enhancement may be more successful conjoined with habitat restoration.

Cryer, M., B. Hartill and S. O'Shea (2002). "Modification of marine benthos by trawling: toward a generalization for the deep ocean?" *Ecological Applications* 12(6): 1824-1839.

Anthropogenic disturbance of deep-sea benthic systems, especially by fishing, has increased markedly in the last 40 years. Deep-sea mining and extraction of fossil fuels can occur at extraordinary intensity at individual sites, but the large number of fishing vessels and their mobility probably makes commercial trawling the most pervasive of our marine activities to depths of up to about 1200 m. Knowledge of the effects of trawling on soft-sediment, benthic communities is, however, limited to shallow, coastal systems, mostly at small spatial scales. We extend that knowledge to deeper systems at the scale of commercial fishing by assessing the effects of bottom trawling in northeastern New Zealand. We characterized the invertebrate catch of 66 research trawls spread along 220 km of continental slope in depths of 200–600 m (encompassing about 2400 km²). At each site, we indexed the intensity of previous trawling using trawl-by-trawl fishing returns. A suite of multivariate analyses revealed that fishing activity was negatively associated (after excluding the effects of depth and location) with invertebrate species richness and diversity and with the density of several taxa. Our models explained up to two thirds of the variation in the invertebrate catch of research trawls. After excluding the effects of depth and location, we attributed 11–40% of total variation to fishing. Concordance among the results of several multivariate methods based on different analytical approaches and assumptions reveals a strong and coherent pattern in the data that is consistent with the predicted and observed effects of trawl fisheries and other sources of physical disturbance. We infer that trawling probably changes benthic community structure and reduces biodiversity over broad spatial scales on the continental slope as well as in coastal systems. Such effects would have important implications for local and regional biodiversity and for the development and management of sustainable fisheries.

Dayton, P. K. (1998). "Reversal of the burden of proof in fisheries management." *Science* 279(5352): 821-822.

Summary: This article addresses the effects of demersal fishing on benthic marine communities, and warns that such activities may potentially alter these habitats to such a degree as to result in "cascading ecological changes," or the inability to return to natural, intact conditions. Furthermore, it is indicated that successive generations of scientists may have different notions of what is natural because they study increasingly altered systems that become less and less similar to the original pristine conditions. The author suggests that firmer restrictions be applied in current fishing practices, and that more emphasis be placed on the

importance of preserving marine systems as opposed to exploiting them for profit.

Dayton, P. K., S. Thrush, T. M. Agardy and R. J. Hofman (1995). "Environmental Effects of Marine Fishing: Aquatic Conservation." *Marine and Freshwater Ecology* v.5: p.205-232.

DeAlteris, J., L. Skrobe and C. Lipsky (1999). The significance of seabed disturbance by mobile fishing gear relative to natural processes: a case study in Narragansett Bay, Rhode Island. American Fisheries Society, Symposium 22. P.-i. L. R. B. e. F. h. e. f. h. a. rehabilitation. Bethesda, Maryland.

Seabed disturbance by mobile bottom-fishing gear has emerged as a major concern related to the conservation of essential fish habitat. Unquestionably, dredges and trawls disturb the seabed. However, the seabed is also disturbed by natural physical and biological processes. The biological communities that utilize a particular habitat have adapted to that environment through natural selection, and, therefore, the impact of mobile fishing gear on the habitat structure and biological community must be scaled against the magnitude and frequency of seabed disturbance due to natural causes. Fishers operating in the mouth of Narragansett Bay, Rhode Island use trawls to harvest lobsters, squid, and finfish and dredges to harvest mussels. These mobile fishing gears impact rock, sand, and mud substrates. Side-scan sonar data from 1995 with 200% coverage were available from the National Oceanic and Atmospheric Administration for the mouth of Narragansett Bay. Analysis of these data indicates that evidence of bottom scarring by the fishing gear is restricted to deeper waters with a seabed composition of soft cohesive sediments, despite the observation that fishing activity is ubiquitous throughout the bay mouth. A quantitative model has been developed to compare the magnitude and frequency of natural seabed disturbance to mobile fishing gear disturbance. Wave and tidal currents at the seabed are coupled with sediment characteristics to estimate the degree of seabed disturbance. Field experiments designed to compare the longevity of bottom scars indicate that scars in shoal waters and sand sediments are short-lived, as compared to scars in deep water and mud sediments, which are long-lasting. Finally, the model results are compared to the recovery time of sediments disturbed by the interaction of the fishing gear with the seabed. The impact of mobile fishing gear on the seabed must be evaluated in light of the degree of seabed disturbance due to natural phenomena. The application of this model on a larger scale to continental shelf waters and seabed sediment environments will allow for the identification of problematic areas relative to the degradation of essential fish habitat by mobile fishing gear.

DeAlteris, J. T., L. G. Skrobe and K. M. Castro (2000). "Effects of mobile bottom fishing gear on biodiversity and habitat in offshore New England waters." *Northeastern Naturalist* v.7(no.4): p.379-394.

Mobile fishing gear affects biodiversity and habitat in New England offshore waters through selective fishing activity, seabed disturbance, and discarding and encounter mortality. Selective fishing activity results in geographically localized impacts on habitat and more widespread impacts on biodiversity through the selective removal of specific species with a higher economic value. Seabed disturbance by fishing activity results in physical impacts related to resuspension of fine sediments and scarring of the seabed, chemical effect due to resuspension of nutrients, and biological impacts related to alteration of the benthic community structure. Discards and other benthic fauna that encounter mobile gear and are impacted by the interaction, temporarily alter the ecosystem dynamic. In general, the habitat impacts are restricted to areas of heavy fishing activity, and in shallower water are ameliorated by natural processes that regularly disturb the seabed. Effects on biodiversity are more widespread due to the transient nature of many impacted species. Mobile fishing gear produces approximately 75% of the landings from New England offshore waters. Habitat impact and a loss of biodiversity may be considered a cost of seafood production. Preservation of habitat and biodiversity in marine sanctuaries and reserves is recommended to balance the effects of fishing. This is analogous to society's management strategy in the terrestrial environment.

Dean, T. A., L. Haldorson, D. R. Laur, S. C. Jewett and A. Blanchard (2000). "The distribution of nearshore fishes in kelp and eelgrass communities in Prince William Sound, Alaska: Associations with vegetation and physical habitat characteristics." *Environmental Biology of Fishes* v.57(no.3): p.271-287.

The nearshore (less than 20 m depth) demersal fish community in Prince William Sound, Alaska, is dominated by Pacific cod, *Gadus macrocephalus*, pricklebacks (mostly Arctic shanny *Stichaeus punctatus*), gunnels (mostly crescent gunnels *Pholis laeta*), a variety of greenlings (*Hexagrammidae*) and sculpins (*Cottidae*). During summer, the spatial distribution of fishes, over scales of 100's of m to 10's of km, varied by habitats characterized by different vegetation types. Juvenile Pacific cod and greenlings were numerically dominant in eelgrass, *Zostera marina*, beds. Pricklebacks and sculpins were dominant in areas with an understory of the kelps *Agarum cribrosum* and *Laminaria saccharina*. Greenlings and sculpins were the most abundant demersal fishes in more exposed sites with a canopy of *Nereocystis luetkeana* and an understory of *L. bongardiana*. Measured habitat variables, including vegetation type, slope, vegetation biomass, and substratum type, explained a significant proportion of the variation in the presence or absence of most fishes. The relative importance of different habitat characteristics varied between taxonomic groups of fishes. Vegetation type explained a significant proportion of variation for cod, rockfishes, and ronquils. Juvenile cod were closely associated with eelgrass, while rockfish and ronquils were associated with kelps. Pricklebacks and rockfishes were more frequently observed on steeply sloped shorelines, while ronquils were more often found at sites with higher biomass of vegetation. Within *A. cribrosum* habitats, more greenlings and sculpins were present at sites where algal biomass was higher.

Also, sculpins were more abundant in deeper water and gunnels were more abundant in shallow water within this habitat. These associations may not have been causative. However, evidence suggests that some differences between fish communities in eelgrass and Agarum beds may have been causally related to vegetation characteristics. The possible roles of different vegetation types as refugia from predators or as sources of prey are discussed.

deGroot, S. (1984). "The impact of bottom trawling on the benthic fauna of the North Sea." *Ocean Management* v.10: p. 21-36.

This paper reviews the impact of bottom trawling --beam-or groundtrawl --on animals of the sea bed. The area of study is restricted to the North Sea, however, the final conclusions have a far wider application. Protests against the use of trawls date back to the period of their introduction; for northwest Europe this was the thirteenth century, and it still evokes protests up to the present day. Trawling does affect benthic life, the trawl penetrates up to 30 mm into the soil, depending on the substrate. All types of trawls are basically similar in their action on the bed. Beam trawls with tickler chains catch much more benthos than do ground trawls without tickler chains. Some groups of animals suffer far more damage than others, e.g., echinoderms. It is not unlikely that in the long-term a shift in species and numbers may occur along the same lines such as has been found in the German Wadden Sea where polychaetes are on the incline and molluscs and crustaceans on the decline.

Demestre, M., S. P. and K. M. J. (2000). The behavioural response of benthic scavengers to otter-trawling disturbance in the Mediterranean. Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. P.-i. M. J. K. a. S. J. d. G. (eds.). Oxford, UK., Blackwell Science Ltd.

Summary [author's summary]: 1) The behaviour of scavengers and predators was studied in response to otter-trawling disturbance in muddy sediments in the north-west Mediterranean. 2) Repeated trawling with a commercial fishing gear over the same plotted coordinates depleted the abundance of commercially important species such as hake. However, smaller scavenging and predatory species increased in abundance significantly with time. 3) As in previous studies, the aggregative response of scavengers was short-lived and lasted no more than several days which indicated that additional food resources made available by the trawling activities were rapidly consumed.

DeVogelaere, A. P., E. J. Burton, W. J. Douros, T. Trejo, Kochevar, R.E., M. N. Tamburri and G. M. Cailliet (2003). Deep-sea corals and resource protection at the Davidson Seamount, California, USA. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Diaz, R., G. Cutter and K. Able (2003). "The importance of physical and biogenic structure to juvenile fishes on the shallow inner continental shelf." *ESTUARIES* v.26(no.1): p.12-20.

Fish-habitat relationships on the shallow inner continental shelf were quantified with video sled and metered beam trawl on Fenwick and Weaver shoals offshore of Maryland and Delaware, U.S. These areas provide megascale physical relief and habitat complexity, but for juvenile fishes, mesoscale and microscale habitat is very important particularly as refuge from predation. At these smaller scales, much of the relief on the inner continental shelf is contributed by bedforms or sand waves and biogenic structures such as tubes, shell beds, or pits. A quantitative association for juvenile fishes between and within benthic habitats was found and related primarily to bedform size and amount of biogenic structure. The incidence of fishes was about four-times higher for large bedforms (> 30 cm wavelength and about 10 cm crest height) relative to smaller bedforms (< 30 cm wavelength and about 5 cm crest height). For biogenic structure, going from high patch-mat tube densities to lower densities or no biogenic structure increased fish incidence by 5.4 and 3.3 times, respectively. The significant relationships of fishes with bedform size and density of biogenic structure indicated that seemingly small differences in physical structure of a habitat can make the difference between unacceptable and essential habitat for juvenile fishes. Proximity of complex and simple habitats was important in the diel use of habitat and in balancing pressure of refuge from predation provided by complex habitats with foraging for increased resources available in simpler habitats. During the day, spatially complex habitats comprised of *Diopatra* and *Asabellides* tube mats had about twice as many fishes relative to bare sandy habitats (8.3-9.9 versus 4.0-4.1 fishes 100 m⁻²), respectively). At night, the pattern was reversed with more fishes present in the bare sandy habitats (12.4-13.5 versus 5.6-8.7 fishes 100 m⁻²). Some fish, such as *Ammodytes* spp., were very habitat specific and occurred only on dynamic coarser sands near the top of the shoals. Others, such as *Urophycis regia*, showed less habitat preference and occurred in all habitats during both day and night. Combining the effects of physical relief and biogenics, the habitat with the highest incidence of fishes had large bedforms with some biogenic structure. More emphasis needs to be placed on quantifying the relationship between fishes and their habitats for the fisheries management concept of essential fish habitat to develop into an effective tool on the inner continental shelf. The juvenile life history stages need to be emphasized because fish-habitat interactions are the strongest for these stages and may be the most ecologically important.

Dieter, B. E., D. A. Wion and R. A. e. McConnaughey (2003). *Mobile Fishing Gear Effects on Benthic Habitats: A Bibliography* (Second Edition). NOAA Technical Memorandum NMFS-AFSC-135. Seattle, WA, Alaska Fisheries Science Center: 206 pp.

Edinger, E. N. R., Michael J. (2000). "Reef classification by coral morphology predicts

coral reef conservation value." *Biological Conservation* v.92(no.1): p.1-13.

Coral reefs can be classified using triangular diagrams based on coral morphology; these taxonomy-independent classes predict several aspects of conservation value for coral reefs. Conservation classes (CC's) of 1, 2, 3 or 4 were assigned to reef sites dominated by massive and submassive corals (CC 1), foliose or branching non-Acropora corals (CC 2), Acropora corals (CC 3), or approximately equal mixes of these three end-members (CC 4). When applied to 15 Indonesian coral reefs, aggregate conservation class, the average of the conservation class of all sites on that reef, was a reliable predictor of coral species richness, habitat complexity, and rare coral species occurrence. Aggregate conservation class predicted these aspects of conservation value more reliably than the reef condition index currently used in southeast Asia, live coral cover, or coral mortality. Definitions of reef status based solely on percentage of live coral cover should be supplemented with other indices such as conservation class that more accurately predict biodiversity value and fisheries potential. Coral morphology triangles and conservation class can be used in zoning marine protected areas and other coral reef biodiversity conservation efforts.

Else, P., L. Haldorson and K. J. Krieger (2002). "Shortspine thornyhead (*Sebastolobus alascanus*) abundance and habitat associations in the Gulf of Alaska." *Fisheries Bulletin* 100(2): 193-199.

Shortspine thornyhead (*Sebastolobus alascanus*) abundance was estimated from 107 video transects at 27 stations recorded from a research submersible in 1991 off southeast Alaska at depths ranging from 165 to 355 m. Numbers of invertebrates in seven major taxa were estimated, as was substrate type. Thornyhead abundance ranged from 0 to 7.5/100 m², with a mean of 1.22/100 m², and was positively correlated with depth and amount of hard substrate. Invertebrate abundances were not significantly correlated with numbers of thornyheads. Shortspine thornyhead abundance estimates from this study were several times higher than estimates

produced by bottom trawl surveys off southeast Alaska in 1990 and 1993, the two years of survey that encompassed the submersible transects; however, the trend of increasing abundance with depth was similar in the trawl surveys and in the submersible transects, suggesting that trawl surveys systematically underestimate abundance of shortspine thornyheads.

Epifanio, C., A. Dittel, R. Rodriguez and T. Targett (2003). "The role of macroalgal beds as nursery habitat for juvenile blue crabs, *Callinectes sapidus*." *JOURNAL OF SHELLFISH RESEARCH* v.22(no.3): p.881-886.

We investigated the role of macroalgal beds as juvenile habitat for the blue crab *Callinectes sapidus*. A 2-year study was conducted in Rehoboth Bay, a lagoonal estuary in the Middle Atlantic Bight along the east coast of North America. Sea grass meadows do not occur in Rehoboth Bay, and submersed aquatic vegetation consists entirely of macroalgae. Quantitative samples were collected from both

vegetated and open (unvegetated) habitat with a throw trap. Results indicate that macroalgal beds provide important habitat for juvenile blue crabs, beginning at settlement and continuing until the crabs reach a carapace width of about 30 mm. Average abundance of juveniles in macroalgal beds was 7 times greater than in adjacent open habitat, and maximum abundance in the beds reached weekly mean values >90 crabs m^{-2} during periods of high recruitment in early autumn. Mean size of individual crabs was 15 mm carapace width when sampling began in May. These crabs had settled the previous autumn and had over-wintered in the bay. Mean size continued to increase through early summer, and the crabs had reached a mean carapace width >30 mm by August. These 30-mm crabs disappeared from the beds in mid-August and were replaced by newly metamorphosed juveniles <10 mm in carapace width. Very small crabs were common in the beds throughout September and October. Results of gut-content analysis imply a direct trophic linkage between indigenous macroalgal production and juvenile crabs collected from the beds. This putative linkage involves various species of amphipods that graze directly on the macroalgae and constitute over 25% (by volume) of the gut contents of juvenile crabs collected from macroalgal habitat.

Etnoyer, P. and L. Morgan (2003). Occurrences of habitat-forming deep-sea corals in the northeast Pacific Ocean. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Fogarty, M. J. and S. A. Murawski (1998). "Large-scale disturbance and the structure of marine systems: Fishery impacts on Georges Bank." *Ecological Applications* Supplement. 8(1): S6-S22.

Georges Bank, a shallow submarine plateau located off the New England coast, has supported valuable commercial fisheries for several centuries. The region is characterized by high levels of primary productivity and, historically, high levels of fish production. Within the last four decades Georges Bank has been subjected to major perturbations that have profoundly altered levels of catch, abundance, and species composition. The arrival of distant water fleets during the early 1960s resulted in dramatic increases in effective fishing effort and the subsequent commercial collapse of several fish populations. Total fish biomass is estimated to have declined by $>50\%$ on Georges Bank during the period of operation of the distant water fleets. The implementation of extended jurisdiction (the 200-mile [370.4-km] limit) in 1977 was followed by modernization and increased capacity of the domestic fleet, resulting in a second perturbation to the system that resulted in further declines in groundfish populations to historically low levels. A subsequent increase in the abundance of species of low commercial value was documented, with an apparent replacement of gadid and flounder species by small elasmobranchs (including dogfish sharks and skates). Examination of feeding guild structure suggests that this switch in species dominance may have been linked to a competitive release. The small elasmobranchs, notably dogfish sharks, also prey on species of commercial importance (primarily small pelagics,

including herring and mackerel). The cumulative impacts on the groundfish populations as a result of intense exploitation and predation pressure may have been further exacerbated by effects of fishing gear on the physical structure of the habitat. Implications for the development of an ecosystem-based management approach are described.

Fossa, J. H., P. B. Mortensen and D. M. Furevik (2002). "The deep-water coral *Lophelia pertusa* in Norwegian waters: Distribution and fishery impacts." *Hydrobiologia* 471(1): 1-12.

The paper presents documentation on the distribution of, and damages to, deep-water reefs of the coral *Lophelia pertusa* in Norwegian waters. The reef areas have traditionally been rich fishing grounds for long-line and gillnet fisheries, and the coral habitat is known to support a high diversity of benthic species. Anecdotal reports claim that trawlers often use the gear, wires, chains and trawl doors to crush the corals and clear the area before fishing starts. To get an overview of the situation, information about the distribution and damage were collected from the literature, fishermen, and our own investigations. The results show that the corals are abundant particularly on the mid Norwegian continental shelf between 200 and 400 m depth. In general it seems that the largest densities are distributed along the continental break and at ridges of morainic origin. The reports from fishermen suggested severe damage to the corals and in situ observations using ROV confirmed the presence of mechanically damaged corals located on trawling grounds. A first estimate of the fishery impact indicates that between 30 and 50% of the reef areas are damaged or impacted. Fishermen claim that catches are significantly lowered in areas where the reefs are damaged. Potential ecological consequences of the destruction are discussed.

Gass, S. E. and J. H. M. Willison (2003). An assessment of the distribution of deep-sea corals in Atlantic Canada by using both scientific and local forms of knowledge. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Gibson, R. N. (1994). "Impact of habitat quality and quantity on the recruitment of juvenile flatfishes." *Netherlands Journal of Sea Research* v.32(no.2): p.191-206.

The effects of the major factors contributing to habitat quality (food, predators, temperature, salinity, oxygen, habitat structure, water depth and hydrodynamics) on the growth and survival of flatfishes during their juveniles stages are described. It is concluded that the first three of these factors are the most important. The impact of habitat quantity on recruitment is also examined and found to play a major role in determining overall population size. Neither habitat quality nor quantity act independently and growth, survival and subsequent recruitment levels of juvenile flatfishes from their nursery grounds must be seen as a result of the interplay between both habitat quality and quantity. The general conclusion is that habitat-related processes on nursery grounds probably serve to

dampen rather than generate recruitment variability.

Gotceitas, V. and J. A. Brown (1993). "Substrate selection by juvenile Atlantic cod (*Gadus morhua*): effects of predation risk." *Oecologia* v.93: p.31-37.

Although predator avoidance has been proposed as one possible factor influencing the distribution of fish among substrate types, no study has addressed this question directly. Groups of juvenile Atlantic cod were offered a choice between pairs of the following three substrates: sand, gravel-pebble and cobble. Their distribution on these substrates was compared prior to, during and following exposure to a predator (i.e. a larger conspecific). With no apparent risk of predation, juvenile cod preferred sand or gravel-pebble. When cobble was present, juveniles hid in the interstitial spaces of this substrate in the presence of a predator. With no cobble present, juveniles showed no preference between sand and gravel-pebble, and did not seek refuge from predation in association with these substrates. Following exposure to a predator (i.e. 2.5 h later) larger juvenile cod again showed a preference for the finer-grained substrates, but smaller individuals continued to associate with the cobble. The presence of cobble resulted in fewer juveniles being captured and a significant increase in the latency until the first juvenile was captured by the predator. Results are discussed with respect to the effects of predation on the distribution and survival of fishes among substrate types.

Gotceitas, V., S. Fraser and J. A. Brown (1995). "Habitat use by juvenile Atlantic cod (*Gadus morhua*) in the presence of an actively foraging and non-foraging predator." *Marine Biology* (Berlin) v.123(no.3): p.421-430.

Experiments were conducted in the autumn and winter of 1992/93 to examine habitat use by juvenile (age 0+) Atlantic cod, *Gadus morhua* L., before, during and following exposure to a passive or actively foraging predator (age 3+ cod). Experiments presented groups of juvenile cod ($n = 5$ fish/group) with one of two combinations of three substrates; (1) gravel, sand, and a patch of artificial kelp ("kelp"), or (2) cobble, sand, and kelp. Cobble is known to provide juvenile cod with a refuge from predation. Kelp was used to test the hypothesis that juvenile cod associate with fleshy macroalgae in nature because of the safety it provides from predators. There was little difference in habitat use by juvenile cod before, during or following exposure to a passive predator. Under these conditions, juvenile cod appeared to prefer finer grained mineral substrates and avoided the kelp. The extent of the juvenile response to a passive predator was to avoid the predator's location in the experimental tank. In contrast, Juvenile cod showed a significant shift in habitat use when exposed to an actively foraging predator, hiding in cobble or, when cobble was not available, in kelp. Use of both these habitats resulted in a significant reduction in predation risk to the juvenile cod. Our results suggest that: (1) an association with kelp provides safety from predation to juvenile cod, and (2) juvenile cod are capable for assessing the risk a predator represents and adjust their response accordingly.

Gotceitas, V., S. Fraser and J. A. Brown (1997). "Use of eelgrass beds (*Zostera marina*) by juvenile Atlantic cod (*Gadus morhua*)." Canadian Journal of Fisheries and Aquatic Sciences v.54(no.6): p.1306-1319.

Two field surveys were conducted in Newfoundland, Canada: (1) SCUBA surveys at four sites differing in bottom type and the presence/absence of vegetation and (2) beach seining at three sites containing eelgrass (*Zostera marina*) and no-eelgrass locations. Results indicated that eelgrass is used as nearshore habitat by age 0+ Atlantic cod (*Gadus morhua*). A subsequent laboratory experiment compared the use of patches of bottom Substrates (sand, gravel, cobble) and artificial eelgrass (three densities) by age 0+ cod when in the absence and presence of a predator (an age 3+ conspecific). Before exposure to a predator, age 0+ cod associated with sand and gravel. With it predator present, in substrate combinations with cobble, age 0+ cod hid in the interstitial spaces of this substrate or in tile patch of eelgrass when stem density was gt 720 stems/ml. In combinations with no cobble, age 0+ cod hid in the eelgrass regardless of stem density. Latency to capture an age 0+ cod was highest and the total number of age 0+ cod captured lowest in combinations with cobble or the patch of vegetation with 1000 stems/ml. In the remaining combinations, latency until an age 0+ cod was captured increased with both the presence and density of vegetation.

Gregory, R. S. and J. T. Anderson (1997). "Substrate selection and use of protective cover by juvenile Atlantic cod *Gadus morhua* in inshore waters of Newfoundland." Marine Ecology Progress Series v.146(no.1-3): p.9-20.

We investigated the habitat preferences and use of cover of 1 to 4 yr old juvenile cod *Gadus morhua* in the inshore waters (18 to 150 m depth) of Placentia Bay, Newfoundland, Canada, using deep sea submersibles (PISCES IV & SDL-1) in April 1995. We analysed a total of 32 h of 'on-bottom' videotape, audiotape, and written records from 9 daylight dives and 1 night dive. Habitat types were characterised by depth, substrate particle size, bathymetric relief, and the presence or absence of macroalgae. Juvenile cod found throughout the dive area were identified as either 'young' (age 1, 10 to 12 cm total length, and mottled in colour) or 'old' (age 2 to 4, gt 15 cm total length, and relatively uniform in colour). Of old juveniles, 80% were found to be associated with areas of coarse substrate and high bathymetric relief (i.e. submarine cliffs). In contrast, 59% of young juveniles were found primarily in areas with a gravel substrate and low relief. Juvenile cod did not exhibit selection for substrates with macroalgae cover. We did not identify any difference between day and night observations. Old juveniles were often associated with individual substrate features (e.g. a single rock, boulder, or crevice), and exhibited a significant increase in activity (oriented swimming speed) with increasing distance from such features. Young juveniles exhibited no such association with specific substrate features, although they exhibited greater variation in activity (non-oriented swimming speed). The observed patterns in activity between the age groups suggest a difference in predator avoidance

behaviour. Young mottled individuals appeared to be relying on crypsis, whereas older uniform-coloured juvenile cod associated with a specific physical feature which represented cover. Our results corroborate the findings of previous laboratory and shallow water field studies on the behaviour of this species. In addition, these results demonstrated that substrate selection by juvenile cod is age specific.

Grehan, A. J., V. Unnithan, A. J. Wheeler, F. X. Monteys, T. Beck, M. Wilson, J. Guinan, J. H. Hall-Spencer, A. Foubert, M. Klages and J. Thiede (2003). Evidence of major fisheries impact on cold-water corals off the Porcupine Bank, West Coast of Ireland: Implications for offshore coral conservation within the European Union. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Gren, I. M. and T. Soderqvist (1994). Economic Valuation of Wetlands: A Survey. Beijer Discussion Paper Series. Stockholm, Sweden, Beijer International Institute of Ecological Economics.

Hall-Spencer, J. M., V. Allain and J. H. Fossa (2002). "Trawling damage to Northeast Atlantic ancient coral reefs." PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON SERIES B-BIOLOGICAL SCIENCES 269(1490): 507-511.

This contribution documents widespread trawling damage to cold-water coral reefs at 840-1300 m depth along the West Ireland continental shelf break and at 200 m off West Norway. These reefs are spectacular but poorly known. By-catches from commercial trawls for deep-water fish off West Ireland included large pieces (up to 1 m²) of coral that had been broken from reefs and a diverse array of coral-associated benthos. Five azooxanthellate scleractinian corals were identified in these by-catches, viz. *Desmophyllum cristagalli*, *Enallopsammia rostrata*, *Lophelia pertusa*, *Madrepora oculata* and *Solenosmilia variabilis*. Dating of carbonate skeletons using C-14 accelerator mass spectrometry showed that the trawled coral matrix was at least 4550 years old. Surveys by remotely operated vehicles in Norway showed extensive fishing damage to *L. pertusa* reefs. The urgent need for deep-water coral conservation measures is discussed in a Northeast Atlantic context.

Hall-Spencer, J. M., C. Frogia, R. J. A. Atkinson and P. G. Moore (1999). "The impact of Rapido trawling for scallops, *Pecten jacobaeus* (L.), on the benthos of the Gulf of Venice." ICES Journal of Marine Science 56(1): 111-124.

Rapido trawls are used to catch sole around the coast of Italy and to catch scallops in the northern Adriatic Sea but little is known about the environmental impact of this gear. Benthic surveys of a commercial scallop ground using a towed underwater television (UWTV) sled revealed an expansive area of level, sandy sediment at 25 m characterized by high population densities of scallops (2.82 m⁻²

Aequipecten opercularis but fewer *Pecten jacobaeus*) together with ophiuroids, sponges, and the bivalve *Atrina fragilis*. Rapido trawls were filmed in action for the first time, providing information on the selectivity and efficiency of the gear together with its impact on the substratum and on the benthos. The trawls worked efficiently on smooth sand with ca. 44% catch rate for *Pecten jacobaeus*, of which 90% were >7 cm in shell height. Most organisms in the path of the trawl passed under or through the net; on average by-catch species only formed 19% of total catch by weight. Of the 78 taxa caught, lethal mechanical damage varied from <10% in resilient taxa such as hermit crabs to >50% in soft-bodied organisms such as tunicates. A marked plot surveyed using towed UWTV before, then 1 and 15 h after fishing by Rapido trawl showed clear tracks of disturbed sediment along the trawl path where infaunal burrow openings had been erased. Abundant, motile organisms such as *Aequipecten* showed no change in abundance along these tracks although scavengers such as *Inachus* aggregated to feed on damaged organisms. There were significant decreases in the abundance of slow-moving/sessile benthos such as *Pecten*, *Holothuria*, and *Atrina*. Juvenile pectinids were abundant on the shells of *Atrina*. The introduction of a scheme of areas closed to trawling would protect highly susceptible organisms such as *Atrina* and enhance the chances of scallop recruitment to adjacent areas of commercial exploitation.

Hall-Spencer, J. M. and P. G. Moore (2000). "Scallop dredging has profound, long-term impacts on maerl habitats." *ICES Journal of Marine Science* 57(5): 1407-1415.

Maerl beds are mixed sediments built by a surface layer of slow-growing, unattached coralline algae that are of international conservation significance because they create areas of high biodiversity. They are patchily distributed throughout Europe (to ~30m depth around the British Isles and to ~120m depth in the Mediterranean) and many are affected by towed demersal fishing. We report the effects of Newhaven scallop dredges on a previously unfished maerl bed compared with the effects on similar grounds that have been fished commercially in the Clyde Sea area, Scotland. Sediment cores were taken to assess the population density of live maerl thalli prior to scallop dredging on marked test and control plots. These plots were then monitored biannually over a four-year period. Live maerl thalli were sparsely distributed at the impacted site, and experimental dredging had no discernible effect on their numbers. The previously unfished ground had dense populations of live maerl and scallops (both *Aequipecten opercularis* and *Pecten maximus*). While counts of live maerl remained high on the control plot, scallop dredging led to a >70% reduction with no sign of recovery over the subsequent four years. The vulnerability of maerl and associated benthos (e.g., the delicate bivalve, *Limaria hians*) is discussed in relation to towed demersal fishing practices.

Hamilton, L. S. and S. C. Snedaker (1984). *Handbook for Mangrove Area Management*. Honolulu, United Nations Environmental Programme and Environment and Policy

Institute, East West Center.

Heck, K. L. J. and T. A. Thoman (1981). "Experiments on predator-prey interactions in vegetated aquatic habitats." *J. Exp. Mar. Biol. Ecol.* 53: 125–34.

Heifetz, J., R. P. Stone, P. W. Malecha, D. L. Courtney, J. T. Fujioka and P. W. Rigby (2003). Research at the Auke Bay Laboratory on Benthic Habitat, Alaska Fisheries Science Center Quarterly Report: 10p.

documented 50% damage to sponges in Eastern GOA one year after a trawl, discussed vulnerability, low recovery rates, and ecological importance of sea whips, and described newly discovered coral gardens, including damage due to bottom fishing gear.

Heikoop, J., D. Hickmott, M. Risk, C. Shearer and V. Atudorei (2002). "Potential climate signals from the deep-sea gorgonian coral *Primnoa resedaeformis*." *HYDROBIOLOGIA* 471, SI: 117-124.

The deep-sea gorgonian coral *Primnoa resedaeformis* has an arborescent skeleton composed of both calcite and a horn-like structural protein called gorgonin. We have investigated potential climate records in corals from Alaska, the eastern seaboard of Canada and the United States, and a Southern Ocean (Pacific sector) seamount. Temperatures at these sites range from 4 to similar to 10 degrees C. $\delta(18)\text{O}$ values of the calcite show strong evidence for isotopic disequilibrium. Extraction of $\delta(18)\text{O}$ paleotemperatures is therefore not straightforward. Sr/Ca data, analyzed by Secondary Ion Mass Spectrometry (SIMS), suggest that temperature might be a control on calcite Sr/Ca in *Primnoa resedaeformis*, but that growth-related kinetic effects could also be important. Based on previous C-14, $\delta(13)\text{C}$ and $\delta(15)\text{N}$ measurements, it has been suggested that particulate organic matter (POM) from the surface is an important carbon source to the polyps and the gorgonin fraction of the *Primnoa* skeleton. $\delta(15)\text{N}$ and $\delta(13)\text{C}$ of polyps and gorgonin show similar regional differences to $\delta(15)\text{N}$ and $\delta(13)\text{C}$ of surface POM. Polyps and contemporaneous gorgonin correlate strongly for both $\delta(13)\text{C}$ and $\delta(15)\text{N}$. The influence of nutrient isotopic composition and climate and productivity variations on the isotopic composition of surface POM may therefore be recorded in gorgonin layers. These corals have very long lifespans (several centuries). The potential exists, therefore, to obtain extended records of surface productivity, deep ocean temperature and chemistry of value to climatologists and fisheries managers.

Henry, L. (2001). "Hydroids associated with deep-sea corals in the boreal north-west Atlantic." *JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM* 81(1): 163-164.

This paper reports on the distribution of epifaunal hydroids associated with deep-

sea corals collected from the boreal north-west Atlantic. Thirteen hydroid species were collected from only four coral specimens, suggesting that northern corals support highly diverse epifaunal communities.

Herrnkind, W. and M. Butler (1994). "SETTLEMENT OF SPINY LOBSTER, PANULIRUS-ARGUS (LATREILLE, 1804) IN FLORIDA - PATTERN WITHOUT PREDICTABILITY." CRUSTACEANA 67(1): 46-64.

We used plankton nets, floating postlarval collectors, and arrays of benthic settling devices, along with diver surveys of juvenile lobster abundance and nursery habitat structure, to estimate the spatial pattern of settlement, abundance of settlers, and characteristics of postsettlement juvenile *Panulirus argus* populations in Florida Bay, the primary nursery for spiny lobsters in Florida. Within a 200 km² region of Florida Bay, settlement was patchy and locally unpredictable, although settlement occurred at most sites each lunar phase. However, the number of postlarvae entering inlets to the bay was significantly correlated with regional settlement, and areas with abundant red macroalgae (settlement substrate) and numerous sponges (benthic juvenile shelter) were the most productive sites, even though settlement within them varied widely during lunar influxes. Floating collector catches accurately estimated the number of postlarvae in the water column at inlets, but results from collectors deployed in the bay did not correlate with the number of postlarvae settling on benthic collectors nearby. Estimates of postsettlement mortality in the field yield a natural mortality of about 97% in the year following settlement.

Hill, A. S., L. O. Veale, D. Pennington, S. G. Whyte, A. R. Brand and R. G. Hartnoll (1999). "Changes in Irish Sea benthos: possible effects of 40 years of dredging." Estuarine Coastal and Shelf Science 48(6): 739-750.

From 1946 to 1951 Dr. N. S. Jones sampled the benthos around the south of the Isle of Man from over 200 sites. Multivariate methods have been used here to compare subsets of this historical data with recent data from the same locations: of these locations some have been subject to heavy scallop dredging over the intervening 40 plus years and some to little dredging. Clear changes were apparent regardless of scallop dredging intensity. Some of the changes in the heavily dredged areas were those expected to result from extreme physical disturbance-an increased polychaete mollusc ratio, loss of some fragile species, and an increase in the predominance of scavenger/predator species. However, changes in the lightly dredged areas also included the loss of a number of species including some potentially fragile tube-dwellers. Reasons for these changes were not apparent.

Holling, C. S. E. (1978). Adaptive environmental assessment and management. New York, NY, John Wiley & Sons.

Hoyt, Z. N., T. C. Shirley, J. J. Warrenchuk, C. E. O'Clair and R. P. Stone (2002). Observations of movement and habitat utilization by golden king crabs (*Lithodes aequispinus*) in Frederick Sound, Alaska.

Male and female golden king crabs (*Lithodes aequispinus*) were collected with commercial crab pots in Frederick Sound, a commercial fishing area in southeastern Alaska, and sonic tags were attached to the carapace of 26 crabs. Tagged crabs were either returned to their collection site or translocated to different depths. Crab movements were monitored May 12-19 with a manned submersible and surface vessels and July 5-8, September 29-October 1 and November 7-11, 2000, with a surface vessel. Depth distribution, dispersal, and associations with conspecifics were analyzed. Substrate type and habitat with which the crabs were associated were videotaped and described; most crabs were in boulder or cobble areas, or on or near vertical walls. Sexes of crabs may have been segregated by depth during our sampling periods and all successfully tagged crabs dispersed from their release site with time. The greatest distance traveled from May to November was 17.5 km, with an average distance traveled of 11.5 km for all successfully tagged crabs. Our observations of 17 pairs of crabs in premating embraces between May 12 and 19 suggests that mid-May is a time in which reproductive activity takes place in this population. Trends in movement from shallow to deeper water, from May 12 (capture and release) until November 11 (final relocation date), were observed for sonically tagged crabs.

Husebo, A., L. Nottestad, J. Fossa, D. Furevik and S. Jorgensen (2002). "Distribution and abundance of fish in deep-sea coral habitats." *HYDROBIOLOGIA* 471,SI: 91-99.

Experimental fishing with long-lines and gillnets was conducted on the continental shelf off southwestern Norway between 150 and 350 m depth. Abundance and distribution of redfish (*Sebastes marinus* L., 1758), ling (*Molva molva* L., 1758), and tusk (*Brosme brosme* Ascanius, 1772) were quantified in *Lophelia pertusa* (L., 1758) coral reefs and in non-coral habitats. The largest catches of redfish were made with long-line fleets set in coral reef habitats. Ling and tusk were also most numerous in coral habitats, although not statistically significant. Fish caught in coral habitats tended to be larger in size than in non-coral habitats. The diet of redfish, tusk and ling included the same prey groups in all habitats, but they differed at the species level. *Lophelia*-reefs may provide a profitable feeding place for tusk. For the planktivorous *Sebastes*, on the other hand, their affinity to the reefs seems primarily to be related to the physical structure offered by the reefs.

Jagiello, T. H., Annette; Tagart, Jack; Zimmermann, Mark (2003). "Demersal groundfish densities in trawlable and untrawlable habitats off Washington: Implications for the estimation of habitat bias in trawl surveys." *Fishery Bulletin* (Seattle) v.101(no.3): p.545-565.

Demersal groundfish densities were estimated by conducting a visual strip-

transect survey via manned submersible on the continental shelf off Cape Flattery, Washington. The purpose of this study was to evaluate the statistical sampling power of the submersible survey as a tool to discriminate density differences between trawlable and untrawlable habitats. A geophysical map of the study area was prepared with side-scan sonar imagery, multibeam bathymetry data, and known locations of historical NMFS trawl survey events. Submersible transects were completed at randomly selected dive sites located in each habitat type. Significant differences in density between habitats were observed for lingcod (*Ophiodon elongatus*), yelloweye rockfish (*Sebastes ruberrimus*), and tiger rockfish (*S. nigrocinctus*) individually, and for "all rockfish" and "all flatfish" in the aggregate. Flatfish were more than ten times as abundant in the trawlable habitat samples than in the untrawlable samples, whereas rockfish as a group were over three times as abundant in the untrawlable habitat samples. Guidelines for sample sizes and implications for the estimation of the continental shelf trawl-survey habitat-bias are considered. We demonstrate an approach that can be used to establish sample size guidelines for future work by illustrating the interplay between statistical sampling power and 1) habitat specific-density differences, 2) variance of density differences, and 3) the proportion of untrawlable area in a habitat.

Johnson, S. W., M. L. Murphy and D. J. Csepp (2003). "Distribution, habitat, and behavior of rockfishes, *Sebastes* spp., in nearshore waters of southeastern Alaska: Observations from a remotely operated vehicle." *Environmental Biology of Fishes* v.66(no.3): p.259-270.

We examined distribution, habitat, and behavior of rockfishes, *Sebastes* spp., with a remotely operated vehicle (ROV) in coastal waters <90 m deep of southeastern Alaska from 1998 to 2000. We identified black, *S. melanops*, canary, *S. pinniger*, China, *S. nebulosus*, copper, *S. caurinus*, dusky, *S. ciliatus*, harlequin, *S. variegatus*, Puget Sound, *S. emphaeus*, quillback, *S. maliger*, redstripe, *S. proriger*, rosethorn, *S. helvomaculatus*, silvergray, *S. brevispinis*, tiger, *S. nigrocinctus*, yelloweye, *S. ruberrimus*, and yellowtail, *S. flavidus*, rockfish. Quillback and dusky rockfish were the most widely distributed species, China and harlequin rockfish were the least widely distributed species. Species richness was greater at sites on or near the outer coast than at sites in more inside, sheltered waters. Most (> 75%) observations of rockfish were over complex bottoms of boulder and rock or in vertical bedrock wall habitats. Few rockfish were observed over soft bottoms with no relief. Median depth of observation was ≈ 30 m for black, copper, dusky, and yellowtail rockfish and >30 m for all other species. Median temperature of observation ranged from 6.1°C for harlequin rockfish to 9.4°C for black rockfish. Size of fish was positively correlated ($p < 0.036$) with depth for dusky, quillback, and yelloweye rockfish. Species often observed alone were China (67%), copper (46%), quillback (46%), and rosethorn (43%) rockfish. Most ($\approx 70\%$) observations of harlequin. Puget Sound, silvergray, tiger, and yelloweye rockfish were in mixed species assemblages. When first observed, the behavior of most rockfish species was

swimming or hovering. Notable exceptions were China, harlequin, rosethorn, and tiger rockfish; 33-57% were resting on bottom or in a hole or crevice.

Jones, J. B. (1992). "Environmental impact of trawling on the seabed: a review." *New Zealand Journal of Marine and Freshwater Research* 26(1): 59-67.

Fishers have been complaining about the effects of bottom trawl gear on the marine environment since at least the 14th century. Trawl gear affects the environment in both direct and indirect ways. Direct effects include scraping and ploughing of the substrate, sediment resuspension, destruction of benthos, and dumping of processing waste. Indirect effects include post-fishing mortality and long-term trawl-induced changes to the benthos. There are few conclusive studies linking trawling to observed environmental changes since it is difficult to isolate the cause. However, permanent faunal changes brought about by trawling have been recorded. Research has established that the degree of environmental perturbation from bottom trawling activities is related to the weight of the gear on the seabed, the towing speed, the nature of the bottom sediments, and the strength of the tides and currents. The greater the frequency of gear impact on an area, the greater the likelihood of permanent change. In deeper water where the fauna is less adapted to changes in sediment regimes and disturbance from storm events, the effects of gear take longer to disappear. Studies indicate that in deep water (> 1000 m), the recovery time is probably measured in decades.

Jones, M., R. Randall, D. Hayes, W. Dunlop, J. Imhof, G. Lacroix and N. Ward (1996). "Assessing the ecological effects of habitat change: Moving beyond productive capacity." *CANADIAN JOURNAL OF FISHERIES AND AQUATIC SCIENCES* v.53 suppl.1: p.446-457.

Productive capacity can be defined as the "ecological effect" end of a habitat change --> ecological effect cause-effect pathway. Determining whether and how a habitat manipulation, either inadvertently or deliberately, will affect productive capacity is the key analytical step of habitat management. We describe a process to ensure that this step is conducted in a manner that is rigorous and relevant. The process has four components: (1) determination of management objectives, (2) identification of indicators, (3) analysis of cause-effect pathways Linking habitat changes to ecological effects, and (4) determination of strategies to effect desirable habitat change. The core of the process is the third step, in which we propose the use of hypotheses-of-effect, a network of cause-effect linkages leading from habitat change to ecological effects, to ensure rigorous assessment of possible effects. We illustrate the process using examples of timber management effects on migratory brook trout (*Salvelinus fontinalis*) and urbanization effects on littoral warmwater communities. We argue that this process, in addition to providing a rigorous means of assessing the evidence relevant to a particular issue, also provides an effective tool for examining uncertainty. We advocate the adoption of this process by management agencies as a method for adaptive habitat management.

Kaiser, M. J. (1998). "Significance of bottom-fishing disturbance." *Conservation Biology* v.12(no.6): p.1230-1235.

Since the early 1970s there has been increasing interest in the ecological effects of bottom-fishing activities on the benthic ecology of the seas of northern Europe. The majority of studies have examined the short-term effects of disturbance on benthic fauna. Some areas, however, such as the southern North Sea, have been subjected to fishing disturbance for over 50 years, which complicates predictions of long-term ecological change inferred from recent experimental studies. I highlight the importance of evaluating the ecological relevance of fishing disturbance versus natural perturbations, which varies among different habitats. Most experimental studies have shown that it is possible to detect short-term changes in community structure in response to fishing disturbance. Evidence suggests that long-term changes are probably restricted to long-lived fragile species or communities found in environments that are infrequently disturbed by natural phenomena. Understanding the relative ecological importance of physical disturbance by fishing versus natural events would provide a basis for predicting the outcome of fishing activities in different marine habitats. I suggest approaches that may refine attempts to correlate fishing intensity and frequency with community change, such as the use of tracking devices fitted to trawlers and surveys of fauna, such as bivalves and echinoderms, that record disturbance events of the past in their shells or body structure.

Kaiser, M. J., J. S. Collie, S. J. Hall, S. Jennings and I. R. Poiner (2003). Impacts of fishing gear on marine benthic habitats. *Responsible fisheries in the marine ecosystem*. M. Sinclair and G. Valdimarsson. Wallingford, Oxon, OX10 8DE, UK, CABI Publishing.

Fishing affects seabed habitats worldwide. However, these impacts are not uniform and are affected by the spatial and temporal distribution of fishing effort, and vary with the habitat type and environment in which they occur. Different fishing methodologies vary in the degree to which they affect the seabed. Towed bottom-fishing gears and hydraulic harvesting devices re-suspend the upper layers of the sedimentary habitat and hence re-mobilize contaminants and fine particulate matter into the water column. The ecological significance of these fishing effects has not yet been determined. Structurally complex habitats (e.g. sea-grass meadows, biogenic reefs) and those that are relatively undisturbed by natural perturbations (e.g. deep-water mud substrata) are more adversely affected by fishing than unconsolidated sediment habitats that occur in shallow coastal waters. Structurally complex and stable habitats also have the longest recovery trajectories in terms of the re-colonization of the habitat by the associated fauna. Comparative studies of areas of the sea bed that have experienced different levels of fishing activity demonstrate that chronic fishing disturbance leads to the removal of high-biomass species that are composed mostly of emergent seabed organisms. These organisms increase the topographic complexity of the seabed and have been shown to provide shelter for juvenile fishes, reducing their

vulnerability to predation. Conversely, scavengers and small-bodied organisms, such as polychaete worms, dominate heavily fished areas. Such a change in habitat may lead to changes in the composition of the resident fish fauna. Fishing also has indirect effects on habitat through the removal of predators that control bio-engineering organisms such as algal-grazing urchins on coral reefs. However, such effects are only manifested in those systems in which the linkages between the main trophic levels are confined to less than ten species. Management regimes that aim to incorporate both fisheries and habitat conservation objectives can be achieved through the appropriate use of a number of approaches, including total and partial exclusion of towed bottom fishing gears, and seasonal and rotational closure techniques. Different management regimes can only be formulated and tested once objectives and criteria for seabed habitats have been defined.

Kaiser, M. J., A. S. Hill, K. Ramsay, B. E. Spencer, A. R. Brand, L. O. Veale, K. Prudden, E. I. S. Rees, B. W. Munday, B. Ball and S. J. Hawkins (1996). "Benthic disturbance by fishing gear in the Irish Sea: a comparison of beam trawling and scallop dredging." *Aquatic Conservation: Marine and Freshwater Ecosystems* 6(4): 269-285.

1) The distribution of effort for the most frequently used mobile demersal gears in the Irish Sea was examined and their potential to disturb different benthic communities calculated. Fishing effort data, expressed as the number of days fished, was collated for all fleets operating in the Irish Sea in 1994. For each gear, the percentage of the seabed swept by those parts of the gear that penetrate the seabed was calculated. 2) For all gears, the majority of fishing effort was concentrated in the northern Irish Sea. Effort was concentrated in three main locations: on the muddy sediments between Northern Ireland and the Isle of Man (otter and Nephrops trawling); off the north Wales, Lancashire and Cumbrian coast (beam trawling); the area surrounding the Isle of Man (scallop dredging). 3) In some areas, e.g. between Anglesey and the Isle of Man, the use of scallop dredges and beam trawls was coincident. A comparative experimental study revealed that scallop dredges caught much less by-catch than beam trawls. Multivariate analysis revealed that both gears modified the benthic community in a similar manner, causing a reduction in the abundance of most epifaunal species. 4) Although beam trawling disturbed the greatest area of seabed in 1994, the majority of effort occurred on grounds which supported communities that are exposed to high levels of natural disturbance. Scallop dredging, Nephrops and otter trawling were concentrated in areas that either have long-lived or poorly studied communities. The latter highlights the need for more detailed knowledge of the distribution of sublittoral communities that are vulnerable to fishing disturbance.

Kaiser, M. J., K. Ramsay, C. A. Richardson, F. E. Spence and A. R. Brand (2000a). "Chronic fishing disturbance has changed shelf sea benthic community structure." *Journal of Animal Ecology* v.69(no.3): p.494-503.

1. Bottom fishing using towed nets and dredges is one of the most widespread

sources of physical disturbance to the continental shelf seas throughout the world. Previous studies suggest that degradation and ecosystem changes have occurred in intensively fished areas. Nevertheless, to date it has been difficult to attribute habitat and benthic community changes to fishing effort at a spatial scale that is truly representative of commercial fishing activities. 2. In this study we present convincing evidence that chronic bottom-fishing disturbance has caused significant and widespread changes in the structure of two distinct soft-sediment benthic assemblages and habitats. 3. Our study compared the benthic fauna found in areas that have been exposed to either high or low levels of bottom-fishing disturbance over the past 10 years. We were able to validate the fishing effort data in some areas using scars in the shells of a long-lived bivalve mollusc (*Glycymeris glycymeris*) which result from fishing disturbance. Shell scars occurred most frequently in bivalves collected from the area of highest fishing effort. 4. Multivariate analyses and the response of abundance/biomass curves indicated that chronic fishing has caused a shift from communities dominated by relatively sessile, emergent, high biomass species to communities dominated by infaunal, smaller-bodied fauna. Removal of emergent fauna has thus degraded the topographic complexity of seabed habitats in areas of high fishing effort. The communities within these areas currently may be in an alternative stable state.

Kaiser, M. J., S. I. Rogers and J. R. Ellis (1999). "Importance of Benthic Habitat Complexity for Demersal Fish Assemblages." *American Fisheries Society Symposium* 22: 212-223.

Major amendments in 1996 to the Magnuson-Stevens Fishery Conservation and Management Act require fisheries managers to define "essential" fish habitat and address the impact of fishing gear in their management plans. However, before considering what might qualify as essential fish habitat, it is necessary to first understand the association between fish and their habitat. Some studies have already revealed subtle relationships between fishes and sediment type; however, this approach does not quantify habitat complexity. We undertook a large-scale survey of demersal fish populations and benthic communities in the southern North Sea and eastern English Channel. As in other studies, water depth was closely linked to the main dichotomy in assemblage composition. Flatfishes occurred in shallow water, whereas roundfishes and small shark species were found in deeper habitats. Within each of these two sample station groupings, the assemblages dichotomized further on the basis of habitat type and benthic faunal associations. Three further groupings were identified within the deepwater habitat. These groupings were characterized by the presence of rocks, broken shells, or a large biomass of sessile epibenthos. Small shark species were almost exclusive to habitats with shelly substrata. In contrast, the shallow-water habitats were topographically less complex with sessile epibenthos of a smaller biomass. Flatfishes that were visual predators were most closely associated with habitats with some sessile epibenthos whereas sole *Solea solea*, which largely locate their prey using chemosensory cues, were more closely associated with the least complex habitat. Although these flatfish habitats are intensively fished by bottom

trawls, the characteristic sessile epifauna are relatively fast growing and are probably able to withstand such disturbance. In contrast, the deepwater sessile communities had sessile epifauna of a greater biomass with some slow-growing species that would be more vulnerable to fishing disturbance. However, these habitats are seldom fished using invasive techniques.

Kaiser, M. J., F. E. Spence and P. J. B. Hart (2000b). "Fishing-gear restrictions and conservation of benthic habitat complexity." *Conservation Biology* v.14(no.5): p.1512-1525.

When two commercially important marine species coexist in the same habitat, conflict may arise between different sectors of the fishing industry. A good example of this situation is when fishers using towed bottom-fishing gear (scallop dredges, beam trawls, and otter trawls) operate in the same areas in which fixed-bottom gear (crab pots) are deployed. We examined an area subject to a voluntary agreement between these two sectors of the fishing industry such that some areas are used exclusively by fixed-gear fishers, some are shared seasonally by both sectors, and others are open to all methods of fishing all year. This agreement was enacted to resolve conflict between the two sectors of the industry. An additional possible benefit of this agreement is the protection of the seabed from towed bottom-fishing gear, which is one of the greatest sources of anthropogenic disturbance of seabed habitats worldwide. Previous studies have demonstrated that complex emergent epifaunal communities are substantially altered by such activities. This habitat alteration in turn influences closely associated species, some of which may be of commercial importance. We undertook comparative surveys of the benthic habitat and communities within the area covered by the agreement and compared different areas subjected to a range of fishing disturbance regimes. Communities found within the areas closed to towed fishing gears were significantly different from those open to fishing either permanently or seasonally. Abundance-biomass curves demonstrated that the communities within the closed areas were dominated by higher biomass and emergent fauna that increased habitat complexity. Areas fished by towed gear were dominated by smaller-bodied fauna and scavenging taxa. Scallop dredges and beam trawls used on more stable habitats appear to have greater impacts on the environment than lighter otter trawls used in shallower water with less stable sediments. It would appear from our data that conflict management in the form of gear-restriction measures has the added benefit of conserving habitats and benthic fauna sensitive to bottom-fishing disturbance.

Kaiser, M. J. and B. E. Spencer (1996). "The effects of beam-trawl disturbance on infaunal communities in different habitats." *Journal of Animal Ecology* 65(3): 348-358.

1) Beam-trawling is a source of physical disturbance to marine sedimentary communities in areas less than 50 m deep, on the western European continental shelf. Chains attached between the beam-trawl shoes are designed to penetrate the upper few cm of the sediment, which leads to the damage or removal of some

infaunal and epifaunal species. In some areas, beam-trawling may be frequent and intense, leading to speculation that it may generate long-term changes in the local benthic fauna. 2) As part of a larger MAFF study examining the ecological effects of beam-trawling, we investigated its local impact on an infaunal community in the north-eastern Irish Sea. Studies of this type are complicated by the heterogeneity of the environment, hence we adopted a replicated, paired control and treatment design to maximize the chances of detecting any effects due to trawling. 3) A side-scan sonar survey revealed that the experimental area was characterized by mobile megaripples in the south-eastern sector of the experimental area and stable sediments with uniform topography in the north-western sector. Multivariate analysis of the species abundances from the control areas separated the fauna into two distinct communities which corresponded to the different substratum characteristics. Data from the two regions were therefore treated separately when testing for the effects of trawling. 4) In the north-western sector, trawling led to 58% decrease in the mean abundance of some taxa and a 50% reduction in the mean number of species per sample. Multivariate analysis revealed that differences between control and fished sites were largely due to the reduction or removal of less common species. These effects were less apparent in the mobile sediments of the south-eastern sector, which had a naturally impoverished fauna and high level of heterogeneity. 5) Univariate variables, such as abundance and the total number of species per sample, indicated that the variation between replicate samples increased as a result of trawling disturbance. However, examination of the community data using an index of multivariate dispersion revealed no difference between fished and unfished areas. This suggests that the effects of fishing disturbance are consistent between replicate samples. 6) Fishing with demersal gears modifies communities in relatively stable sediments. Frequent and repeated physical disturbance by fishing gears may lead to long-term changes in the benthic community structure of these habitats.

Kanno, Y., Y. Ueda and T. Matsuishi (2001). "Subpopulations of Pacific cod *Gadus macrocephalus* off the Pacific coast of Northern Japan." *Nippon Suisan Gakkaishi* v.67(no.1): p.67-77.

Density of the fish shoal and vertebral counts of Pacific cod at various locations in the Sea of Japan and in the Pacific Ocean off the Tohoku District, and in the Pacific Ocean off Hokkaido were studied. Off the Pacific coast, there were three high density areas of fish shoal, i.e., the waters off Sanriku in the Tohoku district, the waters off Cape Esan and the waters off Kushiro in Hokkaido. In the Sea of Japan, there were two high density areas of fish shoal, i.e., the waters off Aomori and Akita prefectures and the waters off Yamagata prefecture. In addition, factor analysis of the monthly catch per seine net showed that the fish in the eastern waters off Cape Erimo, those in the western waters off Cape Erimo, and those in the waters off Sanriku each have peculiar trends of change in the CPUE (catch/net) among monthly catches. Furthermore, the statistical analysis of the vertebral counts showed that the Pacific cod from the eastern waters off Cape Erimo had significantly higher vertebral counts than the Pacific cod in other areas.

The results of the present research and the information on spawning grounds previously reported, suggest that there are three subpopulations of Pacific cod in the present research area in the Pacific Ocean, i.e., a subpopulation in the eastern waters off Cape Erimo, a subpopulation off Cape Esan and a subpopulation off Sanriku District. Further studies are needed to determine the locations of subpopulations of this species in the Sea of Japan.

Kenny, A. J., H. L. Rees, J. Greening and S. Campbell (1998). "The effects of marine gravel extraction on the macrobenthos at an experimental dredge site off North Norfolk, UK. (Results 3 years post-dredging)." ICES CM 2000 -E:08 -Annex 6. V:14: 14 p.

An offshore experimental dredging study was initiated off North Norfolk (UK) in 1992 to investigate the impacts of marine gravel extraction on macrobenthic invertebrates. A dredged 'treatment' and a non-dredged 'reference' site were selected to evaluate the initial impacts and subsequent processes of recolonisation. A survey of the benthos was conducted prior to the removal of about 50,000 tonnes of marine aggregate (sand and gravel) from the treatment site. Thereafter annual monitoring surveys were conducted, the first commencing immediately after the dredging episode. Preliminary results of this study indicated that whilst the dominant species recolonised quickly (i.e. within 8 months after dredging) the biomass remained significantly lower than its pre-dredged state, suggesting possible long-term effects on the community structure. A follow-up study suggested the substantially reduced biomass at the treatment site, some 24 months after dredging, was due to a local increase in sediment transport caused by tide and wave action occurring mainly over the winter period. This paper presents the physical and biological findings 3 years after dredging, and puts forward a generalised model of macrobenthic response to the effects of physical disturbance caused by dredging.

Knowlton, A. and R. Highsmith (2000). "Convergence in the time-space continuum: a predator-prey interaction." MARINE ECOLOGY PROGRESS SERIES 197: 285-291.

Predation is a key structuring mechanism for some marine communities. Prey abundances may fluctuate with strength of predator recruitment and persistence, except in cases where some of the prey population has a refuge in space or time from predation. The sponge *Halichondria panicea* is patchily distributed in the rocky intertidal on the south shore of Kachemak Bay, southcentral Alaska, and in certain locations is the spatial dominant. This long-lived sponge is dispersed by planktonic larvae. At one site *H. panicea* has dominated the mid-intertidal for at least 10 yr. Percent cover estimates show that *H. panicea* averaged 53.4 +/- 9.9% cover from August 1994 through August 1996. A major predator on *H. panicea* is the nudibranch *Archidoris montereyensis*, which is also planktonically dispersed and has an annual life cycle. Predators with larval dispersal have the same obstacles to and potential for recruitment in suitable habitats as planktonically dispersed prey with the added constraint of locating within-habitat prey patches. Total numbers of *A. montereyensis* at the study site (550 m(2)) ranged from 12 to

42 from 1994 to 1996. In the spring of 1997, strong recruitment resulted in an average population of 156 *A. montereyensis* on site from May to July. Percent cover of *H. panicea* declined from visual estimates of 40 % in May to 15 % in July. By August 1997, sponge was absent at the study site and the number of nudibranchs declined to 7 individuals by September. Even though *H. panicea* is abundant in the region and potential recruits should be numerous, as of June 1999, the site once dominated by *H. panicea* is open rock with heavy recruitment of annual macroalgae occurring. The predator-prey relationship of *A. montereyensis* and *H. panicea* is an example of a chase through space and time, with convergence resulting in extreme population fluctuations and an unstable community.

Koenig, C. C., A. N. Shepard and S. Brooke (2003). *Oculina Banks Restoration Project: Description and preliminary assessment*. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Koslow, J. A., G. W. Boechlert, D. M. Gordon, R. L. Haedrich, P. Lorange and N. Parin (2000). "Continental slope and deep-sea fisheries: Implications for a fragile ecosystem." *ICES Journal of Marine Science* 57(3): 548-557.

Exploited deepwater (>500 m) species generally exhibit clear "K-selected" life-history characteristics markedly different from most shelf species: extreme longevity, late age of maturity, slow growth, and low fecundity. Many also aggregate on restricted topographic features such as seamounts, and as a consequence are notably unproductive, highly vulnerable to overfishing, and have potentially little resilience to overexploitation. Since 1964, deepwater fisheries have contributed 800 000-1 000 000 t annually to global marine fish landings. Underlying this apparent overall stability is the "boom and bust" cycle that has characterized many individual fisheries. The accumulated biomass of previously unfished stocks is typically fished down, often within 5-10 years, to the point of commercial extinction or very low levels. Most deepwater stocks are today overfished or even depleted. Depletion of species from deep-sea environments that dominate mid to upper trophic levels may have long-term ecological implications, but the risks of reduced stock size and age structure to population viability, the potential for species replacement, and the impacts on prey and predator populations are not generally known. However, trawl fisheries have been shown to have potentially severe impacts on the benthic fauna of seamounts where these fish aggregate. This fauna, dominated by suspension feeders, such as corals, is typically restricted to the seamount environment and is characterized by high levels of endemism, which suggests limited reproductive dispersal. The ability of the benthic community to recover, following its removal by trawling, is not known.

Koslow, J. A., K. Gowlett-Holmes, J. K. Lowry, T. O'Hara, G. C. B. Poore and A.

Williams (2001). "Seamount benthic macrofauna off southern Tasmania: Community structure and impacts of trawling." *Marine Ecology Progress Series* 213: 111-125.

The benthic macrofauna of a group of small seamounts south of Tasmania was surveyed with a dredge and camera to assess the impact of trawling for orange roughy (*Hoplostethus atlanticus*; Trachichthyidae) and the efficacy of a proposed marine reserve. The seamounts were generally 300 to 600 m high and the peaks ranged from 660 to 1700 m depth. The fauna was diverse: 262 species of invertebrates and 37 species of fishes were enumerated, compared with 598 species of invertebrates previously reported from seamounts worldwide. On seamounts that peaked at depths <1400 m and that had not been heavily fished, the invertebrate fauna was dense, diverse and dominated by suspension feeders, including a matrix-forming colonial hard coral (*Solenosmilia variabilis*) and a variety of hard and soft (gorgonian and antipatharian) corals, hydroids, sponges and suspension-feeding ophiuroids and sea stars. Of the invertebrate species, 24 to 43% were new to science, and between 16 and 33% appeared to be restricted to the seamount environment. Trawl operations effectively removed the reef aggregate from the most heavily fished seamounts. The benthic biomass of samples from unfished seamounts was 106% greater than from heavily fished seamounts and the number of species per sample was 46% greater. Living *S. variabilis* was not found on seamounts peaking at depths >1400 m. These seamounts were dominated by sea urchins and had lower biomass and fewer species per sample. However, few species were restricted to either the shallowest or deepest depths sampled. The fauna unique to the region's seamounts appears to be adequately represented within a recently established 'Marine Protected Area' that encloses 12 seamounts that peak at depths >1150 m.

Kramer, D. L., R. W. Rangeley and L. J. Chapman (1997). Habitat Selection: Patterns of Spatial Distribution from Behavioural Decisions. *Behavioural Ecology of Teleost Fishes*. J. G. J. Godin. Oxford, Oxford University Press: p.37-80.

Laurel, B. J., R. S. Gregory and J. A. Brown (2003a). "Predator distribution and habitat patch area determine predation rates on Age-0 juvenile cod *Gadus* spp." *Marine Ecology Progress Series* v.251: p.245-254.

Eelgrass *Zostera marina* provides refuge to numerous fish species but is vulnerable to fragmentation through natural and anthropogenic disturbance. In Bonavista Bay, Newfoundland, eelgrass patch size was altered to measure changes in predation risk in Age-0 juvenile cod, *Gadus morhua*. Artificial eelgrass mats of 5 sizes (0.32, 1.1, 5.5, 11 and 22 m²) were deployed in duplicate at each of 2 sites in Newman Sound in Terra Nova National Park during summer/autumn in 1999 and 2000. Predator distribution was determined using a combination of weekly underwater transect surveys and biweekly seining. Relative predation rates were measured by tethering Age-0 cod at the center of each patch and recording the incidence of predation (n=1116 tether sets). Predation rates were negatively correlated with patch size during both years, suggesting that larger

patches reduce predator foraging ability. However, high predator densities in the largest eelgrass patch resulted in higher than expected rates of predation. Therefore, habitat dimension affected predation risk in juvenile cod via 2 opposing mechanisms. Our results stress the importance of considering both habitat areal extent and predator distribution when estimating the effects of habitat fragmentation on predation rates.

Laurel, B. J., R. S. Gregory and J. A. Brown (2003b). "Settlement and distribution of Age-0 juvenile cod, *Gadus morhua* and *G. ogac*, following a large-scale habitat manipulation." *Marine Ecology Progress Series* v.262: p.241-252.

In Bonavista Bay, Newfoundland, we monitored patterns of settlement and distribution of 2 species of gadids, Atlantic cod *Gadus morhua* and Greenland cod *G. ogac*, following a large-scale alteration of nearshore eelgrass *Zostera marina* habitat. Comparisons between control and experimental sites, based on bi-weekly sampling from 1995 to 2001, indicated a significant increase in cod abundance at sites enhanced with simulated eelgrass and a corresponding decrease in cod numbers at sites where eelgrass had been removed. These data supported predictions, demonstrating that: (1) there was a sufficient supply of juvenile cod within the areas that have historically been unoccupied (i.e. sand) and (2) both species preferred to settle in complex habitats. However, *G. ogac* responded significantly to the removal of eelgrass in more comparisons than *G. morhua* (70 and 37% respectively), suggesting that *G. ogac* has a higher affinity for complex vegetative habitats than *G. morhua* at the scale of manipulation (ca. 800 m²). Furthermore, despite an overall preference for eelgrass habitat, high within-site catch variation of post-settled juvenile cod indicated that both species were not restricted to a seine site. Such variation was occurring well after the settlement period, suggesting that juvenile cod were moving and occasionally aggregating (i.e. shoaling) throughout the study period. Our results support previously described associations between juvenile cod and eelgrass, but contradict other published accounts of high site-attachment and restricted movement in *G. morhua* following settlement.

Lenihan, H. S. and C. H. Peterson (1998). "How habitat degradation through fishery disturbance enhances impacts of hypoxia on oyster reefs." *Ecological Applications* 8(1): 128-140.

Oysters are ecosystem engineers that create biogenic reef habitat important to estuarine biodiversity, benthic-pelagic coupling, and fishery production. Prevailing explanations for the dramatic decline of eastern oysters (*Crassostrea virginica*) during the last century overlook ecosystem complexity by ignoring interactions among multiple environmental disturbances. To explain oyster loss, we tested whether (1) mortality of oysters on natural oyster reefs varies with water depth (3 m vs. 6 m), (2) harvesting by oyster dredges reduces the height of oyster reefs, and (3) bottom-water hypoxia/anoxia and reduction in reef height through fishery disturbance interact to enhance mortality of oysters in the Neuse

River estuary, North Carolina, USA. The percentage of oysters found dead (mean \pm 1 SD) during a survey of natural reefs in May 1993 was significantly greater at 6-m (92 \pm 10%) than at 3-m (28 \pm 9%) water depth. Less than one season's worth of oyster dredging reduced the height of restored oyster reefs by similar to 30%. During stratification of the water column in summer, oxygen depletion near the seafloor at 6 m caused mass mortality of oysters, other invertebrates, and fishes on short, deep experimental reefs, while oysters and other reef associates elevated into the surface layer by sufficient reef height or by location in shallow water survived. Highly mobile blue crabs (*Callinectes sapidus*) abandoned burrows located in hypoxic/anoxic bottom waters but remained alive in shallow water. Our results indicate that interaction of reef habitat degradation (height reduction) through fishery disturbance and extended bottom-water hypoxia/anoxia caused the pattern of oyster mortality observed on natural reefs and influences the abundance and distribution of fish and invertebrate species that utilize this temperate reef habitat. Interactions among environmental disturbances imply a need for the integrative approaches of ecosystem management to restore and sustain estuarine habitat.

Leverette, T. and A. Metaxas (2003). Predicting suitable deep-sea coral habitat in the northwest Atlantic using environmental factors. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Leys, S. P. and N. R. J. Lauzon (1998). "Hexactinellid sponge ecology: growth rates and seasonality in deep water sponges." JOURNAL OF EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY 230(1): 111-129.

It has been well established that sponges play an important role in benthic ecology as abundant, large, sessile filter-feeders. However, the ecology of one group, the Hexactinellida, whose electrophysiology and cell biology is quite distinct from other Porifera, has received little attention due to the inaccessibility of their preferred deep water habitat. Now, a three year study of a population of the hexactinellid sponge *Rhabdocalyptus dawsoni* (Lambe, 1892) has been carried out in the fjords of British Columbia, Canada. *Rhabdocalyptus* was found to have a patchy distribution in Saanich Inlet, British Columbia, with local abundance reaching 5.3 individuals m^{-2} . The mean length of the tube-like sponges in the inlet was 32 cm (an equivalent of 5.8 l volume) although sponges could reach 87 cm in length (36 l volume). The average growth rate of sponges measured over the course of 3 years was 1.98 cm year⁻¹ (min. - 0.76 cm year⁻¹ max. 5.7 cm year⁻¹) or 167 ml year⁻¹ (min. - 537 ml year⁻¹, max. 556 ml year⁻¹). The rate of tissue regeneration after artificial wounding in the field was 0.05 \pm 0.03 cm² day⁻¹, some 40 times the rate of growth. No recruitment was observed during the study, but mortality of large individuals was seen. Using the calculated growth rate (average rate of increase in volume), the age of an average-sized sponge was estimated to be 35 years. With the assumption that growth rate is constant, large individuals (1 m in length) were estimated to be 220 years old. All

sponges showed seasonal trends in sloughing of the debris-covered outer spicules during winter months (November to February). Increase in outer spicule coat occurred from March to October and sloughing corresponded to the end of seasonal phytoplankton blooms in October or November. These data suggest that hexactinellid sponges have life history strategies and growth rates similar to those of massive tropical and temperate demosponges and that, despite their deep water habitat, they experience seasonality which influences their growth rates and perhaps reproductive period.

Li, H. W., C. B. Schreck and K. J. Rodnick (1984). Assessment of habitat quality models for cutthroat trout (*Salmo clarki clarki*) and coho salmon (*Oncorhynchus kisutch*) for Oregon's coastal streams. Proceedings of a workshop on fish habitat suitability index models. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Division of Biological Services. J. W. Terrell. Washington, D.C. Biological Report 85(6): 57-111.

Lindeboom, H. J. (2000). The need for closed areas as conservation. Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues. P.-i. M. J. K. a. S. J. d. G. (eds.). Oxford, UK, Blackwell Science Ltd.

[author's summary]: 1) A large body of evidence indicates that the long-term changes in benthic communities observed in the North Sea have been caused to a large extent by the direct and indirect effects of fishing activities and not solely by eutrophication, climatic fluctuations and /or pollution. 2) In order to minimize the effects of fisheries, and to move towards the sustainable use and protection of the marine ecosystem, it is necessary to reduce fishing effort, modify gear design and create areas closed to fisheries. 3) The rationale for the creation of closed areas includes: protection of specific species, habitats or juvenile fish, creation of a more natural population age-structure, and the prevention of continuous heavy impacts of certain fishing techniques slowly changing the entire ecosystem. An example for the North Sea is worked out in the text. 4) Closed areas are also for scientific and monitoring purposes. Without them it will be very difficult to study the natural trends in the marine ecosystem or to ascertain which human activity has influenced the ecosystem the most. Furthermore, there may be no value in data that have been collected from areas with an unknown level of fishing disturbance. 5) The size of protected areas should be determined by the objectives of the closure and by the behaviour of species that are characteristic to that area. In such areas, where fisheries and inputs of pollutants will be prohibited or restricted, scientific research into the species composition, abundance and age distribution of different populations should be carried out and trends established. 6) The successful implementation of protected or closed areas requires the definition of clear objectives for the closure. In addition, stakeholders should be included from the beginning of the planning process to design proper, manageable and legally controllable boundaries. Regular monitoring and evaluation programmes should be executed to see if the objectives are met, and to redesign the areas if necessary.

Lindeman, K. C. and D. B. Snyder (1999). "Nearshore hardbottom fishes of southeast Florida and effects of habitat burial caused by dredging." *Fishery Bulletin* (Seattle) U.S. 97(3): 508-525.

Fish assemblages of nearshore hardbottom habitats of southeast Florida were quantified at three sites from April 1994 to June 1996. Random 2 x 15 m transects were visually censused within two replicate areas at each site. The hardbottom at one site was buried by a dredge project to widen a beach one year into the study. A total of 394 transects were sampled. Eighty-six taxa (77 identified to species) from 36 families were censused. Grunts (*Haemulidae*) were the most diverse family (11 species), followed by the wrasses (*Labridae*) and parrotfishes (*Scaridae*) with seven and six species, respectively. The most abundant species were sailors choice (*Haemulon parra*), silver porgy (*Diplodus argenteus*), and cocoa damselfish (*Stegastes variabilis*) with mean abundances (individuals/transect) of 4.5, 3.8, and 3.7, respectively. Early life stages (newly settled, early juvenile, and juvenile) represented over 80% of the individuals at all sites. Newly settled stages of over 20 species were observed in association with hardbottom reef structure. Outside of lagoons, nearshore hardbottom areas are the primary natural structures in shallow waters of mainland Florida's east coast and were estimated to have nursery value for 34 species of fishes. After one year, burial of approximately five ha of hardbottom habitat at one site lowered the numbers of individuals and species by over 30x and 10x, respectively. Due to their early ontogenetic stage, many of these species may not be adapted for high mobility in response to habitat burial. Dredging effects may be amplified by burial prior to and during spring and summer periods of peak larval recruitment.

Lindholm, J., P. Auster, M. Ruth and L. Kaufman (2002). *Fish population responses to sea floor habitat alteration: Implications for the design of marine protected areas*. New York, Springer-Verlag New York Inc.

Lindholm, J. B., P. J. Auster, M. Ruth and L. Kaufman (2001). "Modeling the effects of fishing and implications for the design of marine protected areas: Juvenile fish responses to variations in seafloor habitat." *Conservation Biology* v.15(no.2): p.424-437.

A number of recent studies have linked post-settlement survivorship of Atlantic cod (*Gadus morhua*) with the complexity of the seafloor to which fish settle. Survivorship is greater in habitats of higher complexity (e.g., pebble-cobble substratum with emergent epifauna > pebble-cobble > sand), where cover provides shelter from predators. Fishing with-mobile gear such as bottom trawls and dredges reduces the complexity of seafloor habitats. We used a dynamic model to (1) link patterns in habitat-mediated survivorship of post-settlement juvenile cod with spatial variations in habitat complexity, (2) simulate habitat change based on fishing activities, and (3) determine the role of marine protected areas in enhancing recruitment success. Density-dependent natural mortality was

specified as three alternative functional response curves to assess the influence of different predator foraging strategies on juvenile survivorship during the first 12 months of demersal existence. We applied the model to a theoretical patch of hard-bottom substrata and to a case study based on seafloor habitat distributions at Stellwagen Bank National Marine Sanctuary (Gulf of Maine, Northwest Atlantic). Our results demonstrate that patterns in the shape of response surfaces that show the relationship between juvenile cod survivorship and density as well as movement rate were similar regardless of functional response type, that juvenile cod movement rates and post-settlement density were critical for predicting the effects of marine protected-area size on survivorship, and that habitat change caused by fishing has significant negative effects on juvenile cod survivorship and use of marine protected areas can ameliorate such effects.

Linehan, J. E. G., Robert S.; Schneider, David C. (2001). "Predation risk of age-0 cod (*Gadus*) relative to depth and substrate in coastal waters." *Journal of Experimental Marine Biology and Ecology* v.263(no.1): p.25-44.

Among individuals of a species, mean size in fishes increases with depth in the marine environment according to Heincke's Law. Atlantic cod (*Gadus morhua* L.), like many young fish, are distributed in shallow (<10 m) coastal water through much of their range as young juveniles (age 0) and deeper water as they grow. We tested the hypothesis that juvenile cod occupy such shallows to minimize risk of encounter with larger piscivorous fish whose mean size also increases with depth according to Heincke's Law. In day and night seining, we found that age-0 cod were most abundant in vegetated sites regardless of time period. In vegetated sites, age-0 cod abundance declined at night; the reverse was true at non-vegetated sites. Piscivorous fish were generally most abundant in vegetated sites; there were no consistent differences in abundance between day and night. Relative risk of predation of individual age-0 cod in different habitats, depths and times was determined by tethering. Age-0 cod prey were tethered 25 cm off the bottom in water 0.7, 1.5, 3, 6, 10 and 20 m deep; six times during the day, three times during dusk and three times during the night in 25-min sets on eight dates in August and September 1998. A total of 576 tether sets were deployed. We deployed tethers on two dates for each of two vegetated-eelgrass, *Zostera marina* L.-and two unvegetated sites. Predation on tethered prey was lower at night than during day and dusk at all locations and depths. During day and dusk, predation increased with depth at all sites (approx 3 times higher in deep compared to shallow). At shallow locations (1 to 3 m), predation on tethered prey was generally higher in unvegetated compared to vegetated sites during the day and dusk. Predators were captured in 12% of sets. In order of frequency, these were: cunner *Tautoglabrus adspersus* Walbaum, Atlantic cod, and Greenland cod, *G. ogac* Richardson. Mean size of all predator species captured increased with depth. We showed that predation risk for juvenile fish increases with depth suggesting a behavioural antipredation mechanism for Heincke's Law.

Lipcius, R., W. Stockhausen, R. Seitz and P. Geer (2003). "Spatial dynamics and value of a marine protected area and corridor for the blue crab spawning stock in Chesapeake Bay." *BULLETIN OF MARINE SCIENCE* 72(2): 453-469.

In lower Chesapeake Bay, a 172,235 ha marine protected area and corridor (MPAC) was recently established to protect blue crab adult females either en route to or at the spawning grounds during the reproductive period. The MPAC was justified due to a recent substantial decline in spawning stock biomass. It was situated in waters deeper than 10 in throughout the lower bay due to the high abundances of adult females in this zone, and it was an expansion of a historical spawning sanctuary near the bay mouth to include northward extensions (upper and lower MPACs). We examined spatial dynamics of the blue crab spawning stock in relation to the MPAC through analyses of trawl Survey data (abundances of adult females and egg-bearing females from 1989-1997 and 1995-1997, respectively) partitioned by water depth, time (month and year), and spatial zone (upper MPAC, lower MPAC, MPAC Historical Sanctuary) during the reproductive period (June-September). Adult female abundance peaked at 6-14 m water depths. Consequently, nearly half of all adult females in the lower bay were deeper than 10 in, and therefore protected by the MPAC during the reproductive period, whereas the historical sanctuary protected about 1/3 that of the MPAC. All MPAC segments were utilized by adult females at different times of the spawning season, without consistent use of any particular segment. In contrast, abundance patterns of egg-bearing females were consistent and did not differ by developmental stage of the eggs. Peak abundances of egg-bearing females shifted from the northern to southern portions of the MPAC as the spawning season progressed. Differences in distribution of adult females and egg-bearing females demonstrated the importance of the expanded MPAC to the conservation of the spawning stock, which requires an extensive area to cover seasonal and yearly alterations in distribution. The expanded MPAC is much more effective than the historical sanctuary at protecting a consistent fraction of the blue crab spawning stock over the full spawning season and every year. Both the lower MPAC and historical sanctuary contained high abundances of adult females and egg-bearing females, and these segments therefore potentially function as corridors and spawning grounds. In contrast, whereas adult females were equally abundant in all MPAC segments, egg-bearing females were rarely common in the upper MPAC segment. Hence, the upper MPAC serves primarily as a corridor for females migrating to spawn or hatch their egg masses in the lower MPAC and historical sanctuary. The MPAC protects a major fraction of the spawning stock and spawning grounds both seasonally and yearly, and it encompasses a dispersal corridor for adult females in the deeper waters of Chesapeake Bay. The MPAC therefore serves as a foundation for long-term protection of the blue crab spawning stock, and should be utilized concurrently with complementary management measures to conserve the blue crab population in Chesapeake Bay. Furthermore, the MPAC for the blue crab in Chesapeake Bay may serve as a model system for investigating the value of marine protected areas for exploited marine populations with ontogenetically disjunct stages in the life cycle that encompass diverse habitats.

Loher, T. and D. A. Armstrong (2000). "Effects of habitat complexity and relative larval supply on the establishment of early benthic phase red king crab (*Paralithodes camtschaticus* Tilesius, 1815) populations in Auke Bay, Alaska." *Journal of Experimental Marine Biology and Ecology* v.245(no.1): p.83-109.

Between September 1996 and May 1998, the influence of habitat complexity and larval supply on the establishment of early post-settlement populations of red king crab (*Paralithodes camtschaticus*) was studied in situ in Auke Bay, southeast Alaska. Dive transects and suction dredge surveys conducted during fall 1996 and spring 1998 indicated that late age 0 to 1 + red king crabs were located only in the most complex habitat. This pattern was similar to patterns observed for early age 0 crabs, using settlement pails, during the summer of 1997. Early instars recruited into settlement pails containing ambient sediment at both the rocky cobble and shell-hash sites, but no settlement could be detected in muddy habitat. Population density of benthic age 0 + crab peaked in mid-July, then dropped throughout the summer, and greater densities were always observed in rocky cobble than in shell-hash. Simultaneous use of passive larval collectors ruled out the possibility that these patterns were simply a reflection of larval supply. Rather, the highest levels of larval supply were associated with the muddy site at which no settlement could be detected. The availability of complex habitat, defined simply as substrate rich in available crevice space that is scaled to the body size of the crab instars, appeared to be the primary determinant of the value of nursery habitat, and it is likely to be the critical factor determining early post-settlement survivorship within the population. Such considerations are vital to management of red king crab fisheries where complex nursery habitat is likely to be relatively rare and where conflicts with trawl fisheries and other anthropogenic disturbances to bottom habitat are a potential concern.

Lundalv, T. and L. Jonsson (2003). Cold-water corals in the Skagerrak- more significant than expected but in deep peril. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

MacDonald, D. S., M. Little, N. C. Eno and K. Hiscock (1996). "Disturbance of benthic species by fishing activities: A sensitivity index." *Aquatic Conservation: Marine and Freshwater Ecosystems* 6(4): 257-268.

1) Preliminary estimates of the relative sensitivity of sea bed types and benthic species to physical disturbance, particularly fishing activity, have been made in order to identify areas where further studies are required and to help formulate management plans for sites of marine conservation importance. 2) Physical disturbance is considered in the context of a single encounter with fishing gear followed by a recovery period during which there is no fishing, but with a view to qualifying, in the future, the effect of multiple fishing events. Disturbance is considered in terms of the physical action of the gear on the sea bed and the unit

area over which this action occurs. 3) The effects of a wide range of gears are considered. Static gears, which can be employed on a variety of substrata, generally result in low level impacts for single fishing events and impacts are localized compared with the effects of mobile gears, which can extend over considerable areas. 4) The theoretical sensitivity of individual species is assessed on the basis of how well they cope with an encounter with fishing gear and on their likely recovery from destruction in terms of their reproductive strategies. 5) Species considered of key importance in the structuring of communities are suggested and examples of particularly sensitive species, which are therefore likely indicator species of physical disturbance, are listed. 6) Fragile, slow recruiting animals are considered to be most susceptible to disturbance, while the least sensitive species are generally fast growing and have good recruitment.

Magorrian, B. H. (1995). "The impact of commercial trawling on the benthos of Strangford Lough." Dissertation. i-v + 218 p.

In recent years conflict has arisen between conservation groups and commercial fishing interests over perceived trawl damage to the benthic communities in Strangford Lough. Data from a number of survey techniques were combined to assess the impact of trawling on the benthos of the Lough, principally on the diverse communities associated with the horse mussel, *Modiolus modiolus* beds. The target species of the otter trawl fishery is the queen scallop, *Aequipecten opercularis*. Fisheries data were recorded and a quantitative species bycatch list was compiled. The fishery is confined to a small number of local-based vessels and existing regulations seem adequate. Otter trawls with rollers (separated by discs) on the footrope were found to collect less bycatch, including notably fewer *M. modiolus*, than trawls with a plain, continuous footrope. The major bottom types and associated benthic communities present in the Lough were mapped out using an acoustic bottom classification system, RoxAnn, in conjunction with underwater cameras. Visual data were statistically analyzed to quantify the effects of trawling and certain benthic species were found to be significantly associated with *M. modiolus*. Trawling was found to remove emergent epifauna and to reduce the structural complexity of the mussel bed, giving an overall fattened appearance. Grab sampling was used to further investigate the effects of trawling on benthic community structure, particularly the infaunal component of the benthos. Side-scan sonar was employed to locate areas of the Lough bed physically impacted by trawling. Otter boards were found to imprint distinct trawl marks on the Lough bed and were identified on side-scan records. During the surveys a Geographical Information System (GIS) was successfully employed as a data management tool. Based on this study, possible strategies for future management of the queen scallop fishery and Strangford Lough as a Marine Nature Reserve have been discussed.

Malecha, P. W. and R. P. Stone (2003). Sea whip (Order Pennatulacea) resiliency to simulated trawl disturbance. Second International Symposium on Deep Sea Corals,

Erlangen, Germany.

Mangel, M. (2000). "Trade-offs between fish habitat and fishing mortality and the role of reserves." *Bulletin of Marine Science* v.66(no.3): p.663-674.

Ludwig (1995) argued that (1) management for sustained yield cannot be optimal and (2) effective management models cannot be realistic. I concur, and I begin with the view that sustained yield is more important than maximum yield; indeed maximum sustained yield must become a constraint rather than a target. Mangel et al. (1996) stress that we are very far from managing ecosystems; we manage human interventions in ecosystems. Following Ludwig's advice, I will use a relatively simple model to show how essential fish habitat and fishing mortality are intimately connected-loss of spawning habitat is equivalent to additional fishing mortality on adults. Reserves can help guarantee sustainability of the fishery, even when fishing mortality outside the reserve cannot be very well controlled (despite attempts to do so). In fact, in some circumstances (identified by the model) reserves can simultaneously enhance the stock, protect habitat, and increase catch. Finally, I will show how the model can be used to help resolve the reserve design question, which in this case is how we decide how much spawning habitat and how much of the fishing ground to protect.

McAllister, D. E. a. S., G. (1994). "Trawling and dredging impacts on fish habitat and bycatch." *Coastal Zone Canada '94, Cooperation in the Coastal Zone: Conference Proceedings, Volume 4. Coastal Zone Canada Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada.*: 1709-1718.

Trawling and dredging for fishes, shrimp and shellfish have major impacts on habitat and, through bycatches, fish populations of fishing banks. Tracks of trawlers and dredges swept tracks of over 4.3 million kilometres in 1985. The gear, drawn by powerful vessel engines, shears off bottom vegetation and protruding invertebrate animal life including sea anemones, sponges, sea squirts, crinoids and many others. These miniature forests provide shelter for small species and young of large species from predators and harbor food for fish. Removal of this shelter exposes fish to predation and reduces food supply. The trawls/dredges also shear off higher hummocks, fill in low spots, changing the configuration of the bottom, removing areas more exposed to or protected from the current, exposing shellfish, worms and other sediment dwelling species to predation. Trawling/dredging also stirs up clouds of mud and other sediment that plug gills and similar structures of filter feeders. Bycatches of trawling gear commonly average 50% by weight of the catch. The bycatch, commonly thrown overboard unutilized, is often dead, dying or injured; a few hardy species survive the process. Discarded bottom invertebrates beam trawled in the North Sea suffer mortalities of 30-90%. Thus a significant part of the bottom-living biomass is killed immediately or has its life-span shortened. The bycatch includes young of commercial species, forage species, and species of no direct use to humans but which play a role in ecosystems. Habitat impacts and bycatches affect stocks of

commercial fishes, the natural biodiversity and the ecological services provided. The industrialization of fishing moves the distribution of benefits from individual fishers and fishing communities to larger ports and distant stockholders. It may also extend the periods of time that fishermen are separated from their families. Fishing nations should: (1) undertake regular monitoring of impacts of fishing gear on habitat and non-target species, commercial and non-commercial; (2) undertake ecological studies of sea life in bottom habitats disturbed and undisturbed by different types of fishing gear so as to better understand gear impact; (3) establish near-shore continental shelf and slope protected areas to protect representative ecosystems and species, provide control areas for the study of impacts of fishing gear, areas for scuba diving and submersible tours by ecotourists; (4) switch to fishing gear which has low habitat impact and bycatches; (5) consider the impact of fishing gear on marine biodiversity as well as on commercial fishing stocks; and (6) take into account social as well as environmental factors, equitable distribution of benefits and the quality of life of fishers and fishing communities.

Minns, C. K. and J. E. Moore (2003). "Assessment of net change of productive capacity of fish habitats: The role of uncertainty and complexity in decision making." *Canadian Journal of Fisheries and Aquatic Sciences* v.60(no.1): p.100-116.

Canada's fish habitat management is guided by the principle of "no net loss of the productive capacity of fish habitat" (NNL). Many development proposals are assessed using habitat information alone, rather than fish data. Because fish-habitat linkages are often obscured by uncertainty, uncertainty must be factored into NNL assessments. Using a quantitative framework for assessing NNL and lake habitats as a context, the implications of uncertainty for decision making are examined. The overall behaviour of a net change equation given uncertainty is explored using Monte Carlo simulation. Case studies from Great Lakes development projects are examined using interval analysis. The results indicate that uncertainty, even when large, can be incorporated into assessments. This has important implications for the habitat management based on NNL. First, schemas to specify relative levels of uncertainty using simple habitat classifications can support robust decision making. Second, attaining NNL requires greater emphasis on minimizing habitat loss and creating new areas to compensate for losses elsewhere and less on detailing small incremental changes in modified habitats where the fish response is difficult to demonstrate. Third, the moderate to high levels of uncertainty in fish-habitat linkages require that created compensation is at least twice the losses to reasonably ensure NNL.

Morgan, L., P. Etnoyer, A. Scholz and M. Powell (2003). Conservation and management implications of cold-water coral distributions and fishing effort in the northeast Pacific Ocean. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Morgan, M., C. Wilson and L. Crim (1999). "The effect of stress on reproduction in Atlantic cod." *Journal of Fish Biology* 54(3): 477-488.

This study imposed stress upon spawning cod *Gadus morhua* in the laboratory to evaluate the potential effects of trawl avoidance on their reproductive physiology and spawning behaviour. Plasma cortisol levels of stressed fish were significantly higher than controls. Stressed cod initiated fewer courtships and often performed an altered courtship sequence. Both control and stressed fish spawned and there was little difference in the production of eggs, fertilization rate, hatching success or time to starvation of larvae. However, stressed fish produced abnormal larvae more frequently. Cod exposed to a chronic stressor are able to spawn successfully, but there appears to be a negative impact of this stress on their reproductive output, particularly through the production of abnormal larvae.

Morgan, M. J. and R. Chuenpagdee (2003). *Shifting gears: addressing the collateral impacts of fishing methods in U.S. waters*. Washington, D.C., Pew science series on conservation and the environment: 42 p.

Morgan, M. J., E. M. Deblois and G. A. Rose (1997). "An observation on the reaction of Atlantic cod (*Gadus morhua*) in a spawning shoal to bottom trawling." *Canadian Journal of Fisheries and Aquatic Sciences* 54(Supplement 1): 217-223.

The reactions of Atlantic cod (*Gadus morhua*) in spawning condition to a single pass with an otter trawl were observed by repeatedly transecting the trawl tract through a cod shoal with a 38-kHz echosounding system. The shoal consisted of a 5-km-wide band of fish extending approximately 25 km along the 390-m isobath and occupying the bottom 10 m at varying densities averaging 0.004 fish m⁻³ (maximum 0.488 m⁻³). The shoal comprised cod of a mean size of 41 cm (plus/minus 6.1 cm). Following passage of the trawl, a 300-m-wide "hole" in the aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl. Densities were very low in and near the trawl track and increased up to a distance of 200-400 m on each side of the track (a total distance of 400-800 m). This study is the first to observe large-scale changes in the structure of a shoal of cod in spawning condition, attributable to otter trawling, and indicates that such responses can result in persistent disturbance within the shoal over relatively large distances.

Mortensen, P., M. Hovland, T. Brattegard and R. Farestveit (1995). "DEEP-WATER BIOHERMS OF THE SCLERACTINIAN CORAL *LOPHELIA-PERTUSA* (L) AT 64-DEGREES-N ON THE NORWEGIAN SHELF - STRUCTURE AND ASSOCIATED MEGAFAUNA." *SARSIA* 80(2): 145-158.

Mega fauna on bioherms (large biological structures) of the scleractinian coral *Lophelia pertusa* at 240-290 m depth in the Haltenbanken-Froyabanken area was investigated by video-recording. Sixteen transects from soft bottom with scattered patches of stones below bioherms to top of bioherms were analysed. Fauna

patterns were related to the near-bottom currents. The orientation of the gorgonian *Paramuricea placomus* was used as an indicator of the direction of the main currents at the bioherms. The bioherms were 2 to 31 m high, and had a basal area ranging from 1500 to 50600 m². 36 taxa were identified, of which five taxa only occurred on the bioherms, and five only on the soft bottom with scattered stones. The diversity, H', was highest in the zone of dead *Lophelia*, and lowest on the silty clay. None of the 26 taxa observed on stones were specific for this habitat, but occurred also on the bioherms or the soft bottom. The area with *Lophelia* rubble, near the basis of the bioherms, had the lowest number of taxa(15), but the highest average density of individuals (7.92 ind./10 m²). Different sponges, gorgonians (*Paragorgia arborea*, *Paramuricea placomus*, *Primnoa resedaeformis*), squat lobsters (*Munida sarsi*), redfish (*Sebastes* spp.) and saithe (*Pollachius virens*) dominated in terms of individuals per area. Diversity, density of sponges and density of gorgonians were highest on the down-current side of the bioherms. Saithe were observed with highest densities near the basis of the bioherms, on the up-current side, while redfish had highest densities on the parallel-current side of the bioherm top. These results indicate that near bottom currents and turbulence are factors affecting the fauna on *Lophelia* bioherms.

Mortensen, P. B., L. Buhl-Mortensen, D. C. J. Gordon, G. B. J. Fader, D. L. McKeown and D. G. Fenton (2003). Evidence of fisheries damage to deep-water gorgonians in the Northeast Channel between Georges and Browns Banks, Nova Scotia. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Morton, B. (1996). "The subsidiary impacts of dredging (and trawling) on a subtidal benthic molluscan community in the southern waters of Hong Kong." *Marine Pollution Bulletin* 32(10): 701-710.

The macrobenthic fauna of the southern waters of Hong Kong were surveyed in April 1992, notably with regard to the Mollusca. Subsequently, parts of the area were extensively suction dredged for major construction projects. Commercial trawling continued alongside the dredging. In October 1994, with dredging close to finishing, six of the original 50 stations were resurveyed using the same gear, and the Mollusca again re-examined. This study demonstrates that close to dredged sites, i.e. within 2 km, species and individual numbers of both the Gastropoda and Bivalvia had declined by approximately two thirds in the intervening period. With regard to the Gastropoda, most of the species losses were of specialist neogastropod predators. Post-dredging, the gastropod fauna was virtually dominated by opportunistic scavengers, notably *Nassarius siquijorensis*, *Bursa rana* and *Murex trapa*. These, however, were also dominant pre-dredging and this lends support to an earlier argument that disturbed inshore marine sediments favor the presence of such species. The bivalve fauna was dominated by a few species that are resistant to disturbance, such as *Placamen calophylla*, *Corbula crassa* and *Minnivola pyxidatus*. These species are of no commercial value and the former two have solid shells that are resistant to trawl damage and

which are, actually, adaptations to avoid predation. Possibly, *Veremolpa micra* and *Paphia undulata* are new colonizers of the perturbed sea-bed, but this remains to be substantiated. This study postulates that settling silt plumes associated with dredging activity have exacerbated the problems of a sea-bed already disturbed as a result of trawling and pollution.

Murawski, S., R. Brown, H. Lai, P. Rago and L. Hendrickson (2000). "Large-scale closed areas as a fishery-management tool in temperate marine systems: The Georges Bank experience." *Bulletin of Marine Science* 66(3): 775-798.

Seasonal closed areas have been an element of fishery management in New England waters since 1970 but before 1994 had limited impact on the conservation of groundfish stocks for which they were designed. Beginning in December of 1994, three large areas of historic importance to groundfish spawning and juvenile production on Georges Bank and in Southern New England, totaling 17,000 km², were closed year-round to any gears capable of retaining groundfish (trawls, scallop dredges, gill nets, hook fishing). In the ensuing five years, the closed areas contributed significantly to reduced fishing mortality of depicted groundfish stocks. Placements of the closed areas afforded the greatest year-round protection to the shallow-sedentary assemblage of fishes (primarily flounders, skates, and miscellaneous others) and bivalve molluscs. Although the closures afforded less year-round protection to migratory age groups of Atlantic cod, *Gadus morhua*, and haddock, *Melanogrammus aeglefinus*, additional new regulations in open areas and in the Canadian portions of Georges Bank also contributed to the observed reductions in stock-wide fishing mortality rates. The areas were closed to dredge gear designed for sea scallops, *Placopecten magellanicus*, because of groundfish by-catch (particularly of flounders). Scallop biomass increased 14-fold within the closed areas during 1994-1998. In July 1998, total and harvestable scallop biomasses were 9 and 14 times denser, respectively, in closed than in adjacent open areas. A portion of the closed areas was designated a "habitat area of particular concern" on the basis of patterns of occurrence of juvenile groundfish in gravel/cobble sediment types. Managers reopened portions of one closed area to sea-scallop dredging in 1999, but restrictions on gear and areas fished were used to minimize groundfish by-catch and impact on juvenile cod and haddock on gravel substrates. Results from these reopenings have encouraged managers to contemplate a formal 'area rotation' scheme for scallops intended to improve yield per recruit. Closures of large portions of Georges Bank have proved to be an important element leading to more effective conservation of numerous resource and nonresource species, despite selection of the closed areas on the basis of seasonal spawning grounds of haddock and the distribution of yellowtail flounder, *Limanda ferrugineus*, in southern New England. In the future, factors other than fishing mortality reduction, including optimal placement to enhance larval production and to protect nursery areas and spawning concentrations, may well influence the selection of closed-area boundaries.

Nasby-Lucas, N. M., B. W. Embley, M. A. Hixon, S. G. Merle, B. N. Tissot and D. J. Wright (2002). "Integration of submersible transect data and high-resolution multibeam sonar imagery for a habitat-based groundfish assessment of Heceta Bank, Oregon." *Fishery Bulletin* (Seattle) v.100(no.4): p.739-751.

In the face of dramatic declines in groundfish populations and a lack of sufficient stock assessment information, a need has arisen for new methods of assessing groundfish populations. We describe the integration of seafloor transect data gathered by a manned submersible with high-resolution sonar imagery to produce a habitat-based stock assessment system for groundfish. The data sets used in this study were collected from Heceta Bank, Oregon, and were derived from 42 submersible dives (1988-90) and a multibeam sonar survey (1998). The submersible habitat survey investigated seafloor topography and groundfish abundance along 30-minute transects over six predetermined stations and found a statistical relationship between habitat variability and groundfish distribution and abundance. These transects were analyzed in a geographic information system (GIS) by using dynamic segmentation to display changes in habitat along the transects. We used the submersible data to extrapolate fish abundance within uniform habitat patches over broad areas of the bank by means of a habitat classification based on the sonar imagery. After applying a navigation correction to the submersible-based habitat segments, a good correlation with major boundaries on the backscatter and topographic boundaries on the imagery were apparent. Extrapolation of the extent of uniform habitats was made in the vicinity of the dive stations and a preliminary stock assessment of several species of demersal fish was calculated. Such a habitat-based approach will allow researchers to characterize marine communities over large areas of the seafloor.

Naylor, R. and M. Drew (1998). "Valuing Mangrove Resources in Kosrae, Micronesia." *Environment and Development Economics* 3: 471-490.

NMFS (2004). Website: Resources Assessment and Conservation EngineeringField Videos--Underwater Habitat Footage, Alaska Fisheries Science Center: http://www.afsc.noaa.gov/race/media/videos/vids_habitat.htm. Access Date: April 5, 2004.

Scientists involved with the Habitat Areas of Particular Concern (HAPC) project at the Alaska Fisheries Science Center adapted the design of a "Towed Automatically Compensating Observation System" (TACOS), developed by engineers and scientists at the CSIRO Marine Research laboratories in Hobart, Tasmania, to investigate the demersal (bottom) environment in heavily fished areas around Sequam Pass, Alaska. Video clips 1-9 are footage captured with the TACOS over varying bottom types at different depths. Clips 1-2 show a lush "garden" of sponges and corals (no trawl damage) at 85 meters depth, with Atka mackerel and an occasional sculpin. Clips 3-5 show rockfish habitat at 165 meters with no obvious signs of trawl damage, and northern rockfish, Pacific ocean perch

and one hard to see halibut (clip 5) are apparent. Clip 6 shows massive sand dunes at 170 meters. Clips 7-8 show large rocky outcroppings at 90 meters with spawning male (clip 7) and female (clip 8) Atka mackerel. Clip 9 shows footage of a historical fishing area at 160 meters. Notice the broken-up coral debris in this area -- heavily damaged.

NOAA, O. E. (2002). Exploring Alaska's Seamounts, <http://oceanexplorer.noaa.gov/explorations/02alaska/logs/jul15/jul15.html>. Accessed April 14, 2004.

Norse, E. A. and L. Watling (1999). Impacts of mobile fishing gear: the biodiversity perspective. Fish habitat: essential fish habitat and rehabilitation. P.-i. L. R. B. (ed.). Bethesda, Maryland., American Fisheries Society, Symposium 22.

The increasing concern about impacts of bottom trawling, scallop dredging, and other mobile fishing methods has focused primarily on effects on commercial fisheries, but these fishing activities also act more broadly on benthic biological diversity. Because the seabed is erroneously envisioned as a featureless, nearly lifeless plain, impacts of commercial fishing gear have long been underestimated. Structures on and in the seabed, including biogenic structures (reef corals, kelp holdfasts, shells, tubes, and tunnels) create a diversity of habitat patches. They provide refuges from predations and feeding places for demersal fishes and other species. Benthic structural complexity is positively correlated with species diversity and postsettlement survivorship of some commercial fishes. Mobile fishing gear disturbs the seabed, damaging benthic structures and harming structure-associated species, including commercially important fishes, although some other commercial fish species can persist where seabed structures have been removed. Bottom trawling is therefore similar to forest clear-cutting, but it is far more extensive and is converting very large areas of formerly structurally complex, biologically diverse seabed into the marine equivalent of low-diversity cattle pasture. In contrast with the U.S. National Forest Management Act, which governs use of living resources in federally owned forestlands, the 1996 Magnuson-Stevens Fishery Conservation and Management Act does not prevent ecosystem "type conversion" and ignores the need to maintain biological diversity. Preventing further loss of marine biodiversity and key fisheries will depend on our willingness to protect marine areas from effects of mobile fishing methods.

Persson, L. and P. Eklov (1995). "Prey refuges affecting interactions between piscivorous perch and juvenile perch and roach." *Ecology* (Washington D C) 76: 70-81.

Philippart, C. J. M. (1998). "Long-term impact of bottom fisheries on several by-catch species of demersal fish and benthic invertebrates in the south-eastern North Sea." ICES

Journal of Marine Science 55(3): 342-352.

Within the last few decades, the main bottom fishery in the south-eastern North Sea has changed from otter to beam trawling with beam trawling effort increasing from 1960 onwards. During this period, the Zoological Station in Dm Helder (The Netherlands) has collected and registered by-catch species caught by commercial fishermen. The annual numbers of registered specimens were used to estimate the species-specific catch efficiencies of otter and beam trawlers between 1945 and 1983. This analysis was restricted to fishes (sharks, rays, skates) and 10 invertebrate species (whelks, urchins, squids, crabs) all of which have a demersal life style and were regularly delivered throughout the study period. For most species, the observed variations in annual numbers of fish and invertebrates delivered to the Zoological Station appeared to be related to the changes in type of gear and fishing effort. Results from the model suggest that otter trawlers caught relatively more fish than invertebrates, whilst beam trawlers caught proportionally more invertebrate species (i.e., velvet swimming crab, slender spindle shell) that were rarely delivered during periods of greatest otter trawling effort. On average, the catch efficiency of the beam trawl fleet appeared to be 10 times higher than that of the otter trawl fleet. Furthermore, the trends shown by the model in species delivered suggested that bottom fisheries had a considerable impact on several demersal fish and benthic invertebrates.

Piersma, T., A. Koolhaas, A. Dekinga, J. J. Beukema, R. Dekker and K. Essink (2001). "Long-term indirect effects of mechanical cockle-dredging on intertidal bivalve stocks in the Wadden Sea." *Journal of Applied Ecology* 38(5): 976-990.

There is world-wide concern about the effects of bottom-dredging on benthic communities in soft sediments. In autumn 1988, almost a third of the 50-km super(2) intertidal system around the island of Griend in the western Dutch Wadden Sea was suction-dredged for edible cockles *Cerastoderma edule* and this study assessed subsequent effects. An adjacent area not directly touched by this fishery and an area from which the mussel *Mytilus edulis* beds were removed, served as reference areas. Sediment characteristics, together with the total stock size and settlement densities of *Cerastoderma*, Baltic tellin *Macoma balthica* and soft-shelled clam *Mya arenaria*, were documented during 11 successive autumns before (August-September 1988) and after (August-September 1989-98) the suction-dredging event in fished and unfished areas. Four other areas in the Dutch Wadden Sea, where changes in densities of juvenile bivalves from 1992 to 1998 were measured, served as additional reference locations. Between 1988 and 1994, median sediment grain size increased while silt was lost from sediments near Griend that were dredged for cockles. The initial sediment characteristics were re-attained by 1996. After the removal of all *Mytilus* and most *Cerastoderma*, the abundance of *Macoma* declined for 8 years. From 1989 to 1998, stocks of *Cerastoderma*, *Macoma* and *Mytilus* did not recover to the 1988 levels, with the loss of *Cerastoderma* and *Macoma* being most pronounced in the area dredged for cockles. Declines of bivalve stocks were caused by particularly low rates of settlement in fished areas until 1996, i.e. 8 years after the dredging. A comparison

of settlement in the short (1992-94) and medium term (1996-98) after cockle-dredging in several fished and unfished areas spread over the entire Dutch Wadden Sea, showed a significant negative effect of dredging on subsequent settlement of *Cerastoderma*. *Macoma* also declined, but not significantly. We conclude that suction-dredging of *Cerastoderma* had long-lasting negative effects on recruitment of bivalves, particularly the target species, in sandy parts of the Wadden Sea basin. Initially, sediment reworking by suction-dredging (especially during autumn storms) probably caused losses of fine silts. Negative feedback processes appeared to follow that prevented the accumulation of fine-grained sediments conducive to bivalve settlement.

Pipitone, C., F. Badalamenti, G. D'Anna and B. Patti (2000). "Fish biomass increase after a four-year trawl ban in the Gulf of Castellammare (NW Sicily, Mediterranean Sea)." *Fisheries Research* (Amsterdam) 48(1): 23-30.

This paper deals with a year-round trawl ban implemented in 1990 in the Gulf of Castellammare (NW Sicily, Mediterranean Sea) over an area of about 200 km², with the purpose of fish stock rebuilding. Artisanal and recreational fishing were permitted in the Gulf. To assess the effect of the ban on the abundance of demersal resources, CPUE from experimental trawl surveys carried out before the ban (spring 1987 and 1989) and 4 years after it was in place (spring 1994) were compared. Sampling design was based on three depth strata (10-50, 51-100, 101-200 m); 21 and 30 hauls were made before and after the ban, respectively. Eleven target species (9 finfish and 2 cephalopods) as well as the total catch were used for comparisons. The total catch underwent an 8-fold increase in biomass after the four-year ban, and all the considered species underwent an increase, ranging from 1.2-fold for musky octopus (*Eledone moschata*) to 497-fold for gurnard (*Lepidotrigla cavillone*). The only decrease was for horned octopus (*Eledone cirrhosa*). A management strategy based on year-round trawling bans may prove useful, especially in areas where multispecies and multigear artisanal fisheries make up a large part of the fishing industry. The promising results obtained in the Gulf indicate an approach which might be practicable in areas where pre-existing data useful for traditional assessment and management are poor, or totally lacking, and where resources are already at risk of overexploitation.

Pitcher, C. R., C. Y. Burrige, T. J. Wassenberg and G. P. Smith (1999). "The impact of trawling on some tropical sponges and other sessile fauna." *Memoirs of the Queensland Museum* 44: 455.

Pitcher, C. R., I. R. Poiner, B. J. Hill and C. Y. Burrige (2000). "Implications of the effects of trawling on sessile megazoobenthos on a tropical shelf in northeastern Australia." *ICES Journal of Marine Science* 57(5): 1359-1368.

We estimate the possible overall status of populations of attached seabed fauna

after 20 years of trawling in Australia's Great Barrier Reef (GBR), based on the key results of a five-year experimental study that provided an understanding of faunal resilience, in terms of removal rates per trawl. The removal rates of most seabed fauna were between 5 and 20% per trawl (range 0-40%). In attempting to estimate population status, it was also necessary to review patterns of trawl effort intensity and add a simple model for possible recovery dynamics of fauna. Large areas of the GBR are subject to trawling. In 1996, effort was recorded in 1300 statistical grids, each 6 x 6 minutes, an area equivalent to 153 000 km. Effort was highly aggregated among the grids, with about 20% concentrated into <5% of trawled grounds (intensive); at the other extreme, about 20% of the effort was spread over about 60% of the trawled grounds (extensive). Trawling was also highly aggregated at fine scales within grids; consequently a smaller area is actually trawled than is indicated by summing up 6 min grids. The amount of fauna removed each year is related to the resilience of the fauna to removal, the intensity of trawling, and its degree of aggregation. In lightly trawled grids, the annual removal may have been only a low percentage, but in the most intensively trawled grids, more than 80% of the least resilient fauna may be removed each year. In high-effort grids, aggregated trawling removes smaller amounts of benthos than if effort were distributed randomly or uniformly. The average annual removal of fauna over all trawled grids differs for different fauna. A total of about 4% of high-resilience fauna may be removed, similar to 8% of medium-resilience fauna, and similar to 15% of low-resilience fauna. The overall vulnerability of fauna is a combination of resilience and recovery rates. Fauna with no capacity for recovery will eventually be completely removed from all trawled areas. All fauna with a capacity for recovery have the potential for sustaining a population level in balance with the amount removed by trawling, up to certain limits. The most vulnerable fauna may be completely removed from the 5-10% of grids that are trawled with >2000-3000 h of effort. More fauna will be removed from grids with higher effort. Though 50-70% of trawled grids have been trawled only lightly (<700-1000 h) each year, over the last 20 years there has been a cumulative effect. A generalized depletion across all trawled grids is likely, but fauna with low vulnerability may be depleted by only 3% overall; medium vulnerability fauna may be depleted by about 20%; and highly vulnerable populations may be depleted by about 55% overall. Because of differential vulnerability, the composition of the faunal community will be substantially altered in most grids, with a shift to less vulnerable species.

Poiner, I., J. Glaister, R. Pitcher, C. Burridge, T. Wassenberg, N. Gribble, B. Hill, S. Blaber, D. Milton, D. Brewer and N. Ellis (1998). "Final report on effects of trawling in the Far Northern Section of the Great Barrier Reef: 1991-1996." CSIRO Division of Marine Research, Cleveland, Queensland, Australia. 554 p.

Report Summary: This report covers a five year study into the effects of trawling on seabed communities in the inter-shoal and inter-reef areas in the Far Northern Section of the Great Barrier Reef. The study arose from a GBRMPA convened scientific Workshop in 1989 to address the effects of fishing in the Great Barrier

Reef region. The Workshop recommended that an experimental study of the effects of trawling should be carried out, taking advantage of the area closed to trawling (Marine National Park B) in the Far Northern Section of the Great Barrier Reef Marine Park. CSIRO and QDPI agreed to undertake the study, which was funded by these organizations as well as GBRMPA, FRDC and AFMA. Following the recommendation of the Workshop, the study was sited in an area known as the Green Zone between about 11o 15' and 11o 45'S that was closed to fishing in 1985 as well as in the areas immediately to the north and south of the Green Zone. The study had several components: 1. A collation and review of all known biological, oceanographic, and fisheries information available on the study area (Chapter 2). 2. A description of the study area. This included a survey of the sediments, epi-benthos (animals living on the seabed), fish and prawns in the region (Chapter 2). 3. Comparisons of the areas that are open to trawling with those that are closed to trawling (Chapter 3). 4. A Before-After-Control-Impact (BACI design) manipulative experiment comparing areas that were subjected to the Impact of a single trawl coverage with untrawled Control areas (Chapter 4). 5. A Repeat trawl experiment in which strips of seabed were trawled up to 13 times (Chapter 5). 6. A description of the composition of prawn trawl bycatch and the fate of discards from prawn trawling and a study of the interactions between seabirds and discards (Chapter 6). 7. The results are summarized here in 10 outcomes categories based on the original objectives of the work. In addition we have summarized a model describing the effects of differential impacts and recovery rates of the seabed fauna (Chapter 7). Finally, implications of the findings of the study for management of the GBR and for management of the East Coast prawn trawl fishery are discussed (Chapter 7).

Poiner, I. R. and R. Kennedy (1984). "Complex patterns of change in the macrobenthos of a large sandbank following dredging I. Community analysis." *Marine Biology* (Berlin) 78: 335-352.

The impact of dredging operations on the marine benthos of a large, subtropical, sublittoral sandbank (Middle Banks, Moreton Bay, Queensland, Australia) was investigated during July and August 1982. Statistical comparisons (ANOVA) of species richness, total abundance, Shannon diversity and Shannon equitability were made with extensive pre-dredging data base. Both the dredged and adjacent areas were investigated. Changes in sediments and the distribution and deposition rates of the dredge plumes were also examined. There were significant decreases (P less than or equal to 0.025) in the species richness (from 33.0 to 16.6 mean number of species per site), total abundance (from 117.9 to 47.6 mean number of individuals per site) and Shannon diversity (from 4.03 to 3.22 mean diversity per site) within the dredged area. There were significant increases (P less than or equal to 0.01) in species richness (from 31.2 to 67.9 mean number of species per site) and total abundance (from 177.7 to 752 mean number of individuals per site) in adjacent benthic areas. The distribution and the predicted deposition rates of the sediment plume correlated precisely with the area of enhancement (P less than 0.05). The potential causal relationship between deposition and faunal

enhancement is discussed. We suggest that the enhanced effect is probably a response of the benthic biota to an increase in available resources.

Probert, P. K., D. G. McKnight and S. L. Grove (1997). "Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand." *Aquatic Conservation: Marine and Freshwater Ecosystems* 7(1): 27-40.

1. Benthic invertebrate bycatch was collected during trawling for orange roughy (*Hoplostethus atlanticus*) at water depths of 662-1524 m on the northern and eastern Chatham Rise, New Zealand, in July 1994. Seventy-three trawl tows were examined, 49 from 'flat' areas and 24 from two groups of 'hills' (small seamounts). Benthos was recorded from 82% of all tows. 2. Some 96 benthic species were recorded including Ophiuroidea (12 spp.), Natantia (11 spp.), Asteroidea (11 spp.), Gorgonacea (11 spp.), Holothuroidea (7 spp.), and Porifera (6 spp.). 3. Cluster analysis showed the bycatch from flats and hills to differ significantly. Dominant taxa from flats were Holothuroidea, Asteroidea and Natantia; whereas taxa most commonly recorded from hills were Gorgonacea and Scleractinia. Bycatch from the two geographically separate groups of hills also differed significantly. 4. The largest bycatch volumes comprised corals from hills: Scleractinia (*Goniocorella dumosa*), Stylasteridae (*Errina chathamensis*) and Antipatharia (?*Bathypates platycaulus*). Such large sessile epifauna may significantly increase the complexity of benthic habitat and trawling damage may thereby depress local biodiversity. Coral patches may require > 100 yr to recover. 5. Other environmental effects of deep-water trawling are briefly reviewed. 6. There is an urgent need to assess more fully the impact of trawling on seamount biotas and, in consequence, possible conservation measures.

Quigley, M. P. and J. A. Hall (1999). "Recovery of macrobenthic communities after maintenance dredging in the Blyth Estuary, north-east England." *Aquatic Conservation: Marine and Freshwater Ecosystems* 9(1): 63-73.

This paper examines the impact of a dredging event on the benthic community of a polluted estuary in north-eastern England and follows recovery of the community from January until June, 1997. Adopting a BACI (Before, After, Control, Impacted) approach, the benthos were sampled at two sites using a Haps corer (0.0143 m super(2)). Five cores were taken at each site, and the sites were each visited once in January 1997, prior to the 33 day dredging period, and a further five times during the 100 day post-dredging monitoring period ending in June 1997. Fifteen taxa were recorded, of which five contributed 95% of all of the individuals present; *Capitella capitata* (Fabricius), *Tubificoides* spp., nematodes, *Eteone longa* (Fabricius), and the mollusc *Angulus tenuis* (da Costa). Univariate and multivariate analyses of benthic macrofaunal data showed that dredging had not only impacted the dredged site, but had also affected the control area located 500 m away on the opposite side of the estuary. At the end of the study period the macrobenthic community at the impacted site showed no significant signs of recovery to pre-dredging community parameters.

Reed, J. K. (2002). "Deep-water *Oculina* coral reefs of Florida: Biology, impacts, and management." *Hydrobiologia* 471(1): 43-55.

Deep-water *Oculina* coral reefs, which are similar in structure and development to deep-water *Lophelia* reefs, stretch over 167 km (90 nmi) at depths of 70–100 m along the eastern Florida shelf of the United States. These consist of numerous pinnacles and ridges, 3–35 m in height. Coral growth rates average 16.1 mm yr⁻¹ and biodiversity is very rich. Extensive areas of *Oculina* rubble may be due to human impacts (e.g. fish trawling and dredging, anchoring, bottom longlines) and natural processes such as bioerosion and episodic die-off. Early in the 1970s, the reefs were teeming with fish. By the early 1990s, both commercial and recreational fisheries, including scallop, shrimp, grouper, snapper and amberjack, had taken a toll on the reefs and especially on populations of grouper and snapper. A 315 km² (92 nmi²) area was designated the *Oculina* Habitat of Particular Concern (HAPC) in 1984, prohibiting trawling, dredging, bottom longlines and anchoring, and legislation was enacted in 2000 for expansion of the *Oculina* HAPC to 1029 km² (300 nmi²). The United States Coast Guard has been charged with surveillance and enforcement of the ban on bottom fishing and trawling. The primary difficulties in protecting these reefs and other deep-water Marine Protected Areas are their remoteness and time required to engage an enforcement vessel. Education regarding the nature and importance of these rich resources is important for better self regulation and surveillance by the fishing community. Only by bringing deep-water reefs to the public, the fishing community, and enforcement agencies, through video, photos, and education will there be better understanding and acceptance for the need of protection for these unseen resources. This paper reviews the current knowledge on the deep-water *Oculina* reefs, including the biology, geology, human impacts, and history of conservation and management.

Reed, J. K., A. N. Shepard and C. C. Koenig (2003). Mapping and habitat characterization of the deep-water *Oculina* coral reef marine protected area: past and present. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Reise, K. and A. Schubert (1987). "Macrobenthic turnover in the subtidal Wadden Sea: The Norderaue revisited after 60 years." *Helgolander Meeresuntersuchungen* 41(1): 69-82.

The benthic macrofauna of tidal inlet in the northern Wadden Sea was sampled with grab and dredge in 1924-1926, and again in 1985 and 1986. The comparison of surveys from consecutive years, as well as observations from an adjacent area, are employed to separate spurious from real long-term changes. Several epibenthic species of the 1920s became rare or absent in the 1980s. Oyster beds and reefs of the colonial polychaete *Sabellaria spinulosa* have disappeared completely. On the other hand, mussel beds have extended their range, and the

abundance of mobile infauna has increased. The total number of species has remained approximately the same. Compared to surveys from consecutive years, the 60-year interval has doubled the species turnover rate, and has decreased the similarity in relative abundances by one third. The observed losses are best explained by the impact of dredging and trawling on the benthic fauna, while gains seem to indicate coastal eutrophication.

Relini, G., M. Relini and G. Torchia (2000). "The role of fishing gear in the spreading of allochthonous species: the Case of *Caulerpa taxifolia* in the Ligurian Sea." *ICES Journal of Marine Science* 57(5): 1421-1427.

Qualitative and quantitative changes in fish communities are described when a sea grass (*Cymodocea nodosa*) is replaced by a green alga (*Caulerpa taxifolia*) at Imperia (western Ligurian Sea). In general, the number of species, number of individuals and weight increase when the soft bottom is colonized by the alga, but the catch of valuable fish, and consequently the fishermen's income, decrease. The spreading of the alga is facilitated by fishing activity, in particular by bottom trawlers and trammel nets. Fishermen are themselves strongly affected by the spreading, not only because of the decrease in valuable fish, but also because the massive presence of the alga interferes with the use of the gear.

Reuter, R. F. and P. Spencer (2003). "Characterization of rockfish (*Sebastes* spp.) habitat in the Aleutian Islands using historical data." *American Fisheries Society Annual Meeting* v.133: p.269-270.

The essential habitats of rockfishes in the north Pacific are not well understood. Information about the community structure of co-occurring rockfish species, the spatial structure of these communities and their temporal persistence would aid in defining their essential habitat as well as in the management of their fisheries. It is known that certain individual rockfish species can be distributed non-uniformly or uniformly within discrete depth zones throughout the north Pacific. For instance, in depths less than 300 m the greatest densities of Pacific ocean perch (*Sebastes alutus*) are generally found in patches, whereas those of roughey rockfish (*S. aleutianus*) and shortraker rockfish (*S. borealis*) are distributed more uniformly along the slope at depths greater than 300 m. Differences in habitat types between the high and low density areas of rockfish are not well understood. In this study, research survey data (1980-2000) was used to conduct analyses describing rockfish distributions and species associations in the Aleutian Islands. Clusters of survey haul locations similar in species composition were produced from hierarchical cluster analysis and mapped with a GIS. The resulting clusters were then characterized with respect to species composition, depth, temperature and temporal persistence. The results from these studies may aid in describing essential rockfish habitat and identify areas potentially suitable for spatial management of rockfish fisheries.

Reyes, J., N. Santodomingo, A. Gracia, G. Borrero, L. M. Mejia-Ladino, A. Bermudez and M. Benavides (2003). Biodiversity survey of south Caribbean deep-sea coral communities. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Richards, L. J. (1986). "Depth and habitat distributions of three species of rockfish (Sebastes) in British Columbia: [Canada] observations from the submersible PISCES IV." ENVIRONMENTAL BIOLOGY OF FISHES v.17(no.1): p.13-22.

I describe a technique to quantify spatial distribution patterns of deep reef-fishes, and apply this technique to inshore rockfish (Sebastes) communities in the Strait of Georgia, British Columbia, Canada. Observations were made along vertical transects between 21-140 m using the submersible PISCES IV. A total of 31 transects were completed at 14 sites during 16 submersible dives. *S. elongatus*, *S. maliger* and *S. ruberrimus* were the dominant rockfish species that were observed. *S. elongatus* and *S. ruberrimus* had similar depth distributions, but tended to segregate by habitat type. *S. elongatus* was most abundant on mud and cobble substrates that interspersed rocky areas. *S. maliger* and *S. ruberrimus* were both abundant in complex rock habitats, but tended to segregate by depth. For all three species there was an increase in size with depth. Hence, habitat type and depth were important influences on distribution patterns of this species group.

Richards, L. J. (1987). "Copper rockfish (*Sebastes caurinus*) and quillback rockfish (*Sebastes maliger*) habitat in the Strait of Georgia, British Columbia [Canada]." REVUE CANADIENNE DE ZOOLOGIE v.65(no.12): p.3188-3191.

Densities of copper rockfish (*Sebastes caurinus*) and quillback rockfish (*Sebastes maliger*) differ significantly among sites in the northern Strait of Georgia. To determine whether among-site density differences are associated with habitat characteristics of the sites, rockfish densities and habitat characteristics were measured at 12 sites during SCUBA surveys in 1984 and 1985. Quillback rockfish densities were greater in areas of high relief, broken rock, and high percentage cover of flat-bladed kelp, especially on deep transects. Copper rockfish densities were also greater in high relief areas, but effects of other habitat characteristics were not significant. Copper rockfish appeared to be more widely distributed than quillback rockfish over the range of habitats and depths surveyed.

Riesen, W. and K. Reise (1982). "Macrobenthos of the subtidal Wadden Sea: revisited after 55 years." Helgolander Meeresuntersuchungen 35(4): 409-423.

During the years 1923-1926, Hagmeier & Kaendler (1927) sampled the macrofauna of subtidal shallows and channels of the Wadden Sea close to the Island of Sylt (German Bight, North Sea). Reinvestigating this study area in 1980, a substantially altered faunal composition was recorded. An approach is made to quantify the comparison in terms of abundance, species richness and diversity of invertebrate taxa. Human interference is assumed to be responsible for the major changes. Natural oyster beds have been overexploited and the local population of

Ostrea edulis has been driven to extinction. Subsequently, mussels (*Mytilus edulis*) spread in the entire region, promoted by shell fishery. Particularly barnacles and many polychaetes took advantage of the expansion of mussel banks which is substantiated by correlation analysis. Reefs of the colonial polychaete *Sabellaria spinulosa* stood in the way of shrimp trawling and became destroyed together with the associated fauna. A subtidal *Zostera marina* bed was wiped out in 1934 by a natural epidemic disease but never succeeded in reestablishing itself. The associated fauna disappeared. Large epibenthic predators and scavengers (crabs, snails and starfish) survived all these changes. The total number of species remained approximately at the same level but molluscs experienced losses and polychaetes diversified. Overall abundance increased with a disproportionately large share of a few species (*Mytilus edulis*, *Balanus crenatus*, *Cerastoderma edule*, *Scoloplos armiger*). The subtidal fauna of the Wadden Sea proved to be vulnerable to human disturbance; thus, the present community can no longer be viewed as the outcome of entirely natural processes.

Risk, M. H., JM ; Snow, MG ; Beukens, R (2002). "Lifespans and growth patterns of two deep-sea corals: *Primnoa resedaeformis* and *Desmophyllum cristagalli*." *HYDROBIOLOGIA* v.471, SI: 125-131.

A subfossil fragment of the deep-sea gorgonian coral *Primnoa resedaeformis* was C-14 AMS dated along a radial growth transect. Dates ranged from 2600 \pm 50 at the outside, to 2920 \pm 60 C-14 years BP near the interior, suggesting an age of >300 years. The average radial growth was approximately 0.044 mm.yr⁻¹. Based on comparisons with live-collected specimens, we estimate the entire colony may have been about 0.5-0.75 m tall, with a linear tip extension rate of 1.5-2.5 mm.yr⁻¹. Towards the centre of the main stem, the coral skeleton is composed of alternating couplets, 200 μ m in width, of gorgonin (a horn-like organic skeletal protein) and calcite. We believe these couplets are annual. Within this larger scale of banding are finer couplets of gorgonin and calcite, with frequencies suggesting lunar monthly periodicity. Both scales of banding may reflect fluctuations in food supply from sinking POM, or from tidally-resuspended bottom POM, along with benthic consumers. Outer skeletal growth is predominantly massive calcite with intermittent gorgonin layers. If carbonate precipitation in this zone were continuous, approximately 25 μ m radial growth would be deposited every year. The Scleractinian *Desmophyllum cristagalli* lives to >200 years, and has rates of linear extension of 0.5-1.0 mm.yr⁻¹. The skeletons show growth bands approximately 10 μ m wide, which may be annual. Due to tissue extension and retraction in life, parts of the skeleton may be overgrown, or suffer dissolution. Although we have shown in previous publications that sea water temperatures may be obtained from analysis of this coral, periods of skeletal dissolution, coupled with isotopic disequilibrium, will make obtaining long climatic records extremely difficult.

Roark, E. B., T. Guilderson, S. Flood-Page, R. B. Dunbar and B. L. Ingram (2003).

Radiocarbon based age and growth rates estimates on deep-sea corals from the Pacific. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Roberts, C. M. (2002). "Deep impact: the rising toll of fishing in the deep sea." *Trends in Ecology and Evolution* 17(5): 242-245.

Roberts, J. M., S. M. Harvey, P. A. Lamont, J. D. Gage and J. D. Humphery (2000). "Seabed photography, environmental assessment and evidence for deep-water trawling on the continental margin west of the Hebrides." *Hydrobiologia* 441(1-3): 173-183.

A photographic survey in 1998 of the seabed along depth transects from 700 to 1300 m across the N.E. Atlantic continental slope off north-west Scotland shows clear depth-related change in sediment type and megabenthic community in an environment where biological communities and species distributions are poorly known. Small-scale features, such as trawl marks and dense fields of xenophyophores, were resolved that may have remained unknown using conventional sampling or lower resolution imaging techniques. Because xenophyophores accumulate barite, a constituent of some drilling muds, their local-scale occurrences will be important to baseline environmental survey prior to hydrocarbon prospecting in deep water. Our results indicate that deep-sea trawling is physically impacting the seabed to depths of more than 1000 m. The persistence and biological consequence of this impact is unknown, but may depend on sediment type and natural physical disturbance. Comparison with similar seabed photographs taken from a neighbouring area in 1988, which show a high incidence of trawl marks, indicates that such impacts have been taking place over at least 10 years.

Roberts, S. and M. Hirshfield (2004). "Deep-sea corals: out of sight, but no longer out of mind." *Frontiers in Ecology and the Environment* 2(3): 123-130.

Two-thirds of all known coral species live in waters that are deep, dark, and cold. Yet due to the difficulty of researching them in their natural environment, their biology and ecology are poorly understood. Deep-sea coral communities provide habitat for many vertebrate and invertebrate species, including some commercially important fish and crustacean populations. Some have levels of biological diversity comparable to shallow-water reefs. They are also highly susceptible to disturbance from many of our deep-sea activities. Bottom trawling in particular has caused considerable destruction of these communities around the world. Due to their extreme longevity and slow growth, recovery is likely to be in the order of decades or even centuries. We provide an overview of deepwater coral biology and ecology, identify the more manageable threats, and suggest recommendations to mitigate further loss.

Rocha, L., I. Rosa and B. Feitoza (2000). "Sponge-dwelling fishes of northeastern

Brazil." ENVIRONMENTAL BIOLOGY OF FISHES 59(4): 453-458.

In this first attempt to survey the Brazilian sponge-dwelling fishes we present a list of collected fishes, with notes on their distribution, abundance and habitat preferences. *Risor ruber*, an obligate sponge-dwelling goby, and *Scorpaenodes tredecimspinosus*, never before collected in association with sponges, are recorded for the first time in the western South Atlantic based on collections made in localities on the northeastern Brazilian coast. Previous work on *Risor ruber* indicated that it preferred massive sponges, but in our study the majority of the specimens were found in the lumen of tubular sponges, *Aplysina lacunosa*, together with other fishes and invertebrates, mostly crustaceans. *Elacatinus figaro*, originally described as a cleaner goby, is also a sponge-dweller that occurs in waters much deeper than previously thought. The sponge community off northeastern Brazil represents the only shelter for several species of fishes in a desert of rubble and flat rocky bottoms, perhaps functioning as habitat 'oases'. We also found four Brazilian endemic species of fishes associated with sponges in depths greater than 50 m, which contradicts a previous hypothesis suggesting that endemic fishes in Brazilian coastal waters are restricted to depths less than 50 m.

Rodwell, L. D., E. B. Barbier, C. M. Roberts and T. R. McClanahan (2003). "The importance of habitat quality for marine reserve - fishery linkages." Canadian Journal of Fisheries and Aquatic Sciences v.60(no.2): p.171-181.

We model marine reserve - fishery linkages to evaluate the potential contribution of habitat-quality improvements inside a marine reserve to fish productivity and fishery catches. Data from Mombasa Marine National Park, Kenya, and the adjacent fishery are used. Marine reserves increase total fish biomass directly by providing refuge from exploitation and indirectly by improving fish habitat in the reserve. As natural mortality of the fish stock decreases in response to habitat enhancement in the reserve, catches increase by up to 2.6 tonnes (t) $\text{km}^{-2} \text{year}^{-1}$ and total fish biomass by up to 36 t km^{-2} . However, if habitat-quality improvement reduces the propensity of fish to move out of the reserve, catches may fall by up to 0.9 t $\text{km}^{-2} \text{year}^{-1}$. Our results indicate that habitat protection in reserves can underpin fish productivity and, depending on its effects on fish movements, augment catches.

Rogers, S. I., D. Maxwell, A. D. Rijnsdorp, U. Damm and W. Vanhee (1999). "Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. IV. Can comparisons of species diversity be used to assess human impacts on demersal fish faunas?" Fisheries Research (Amsterdam) 40(2): 135-152.

Patterns in the abundance of commercially important and non-target demersal fish species collected by beam trawl survey from the coastal waters of the northeast Atlantic are described. Catches were dominated by a small number of species, which occurred in large numbers and at high biomass. The most abundant species (plaice and dab) were typical of shallow, uniform sandy and muddy seabed which occurred extensively throughout the southern North Sea, and to a limited extent in

UK western waters. Renyi's diversity index family was used to rank the diversity of coastal sectors throughout the region. The less species-rich North Sea fauna, partly a result of the uniform nature of the seabed, was largely responsible for lower diversity of North Sea coastal faunas compared to those in the Channel and west of the UK. West of the Dover Strait, the more heterogeneous substrate supported a more diverse fauna of smaller sized fish, with the occurrence of southern species such as red gurnard and thickback sole and an increasing abundance of elasmobranchs. In the Irish Sea, fish biomass was dominated by plaice and dab, but to a lesser extent than on the continental coast of the North Sea. Sole, lesser spotted dogfish and cod were also important in this assemblage. Patterns in community structure over such a wide spatial scale, and without historical perspective, can be explained by biogeographic factors, seabed structure and the influence of regional hydrography. Inferring from these patterns an impact of anthropogenic factors (such as towed fishing gears) is unlikely to be achieved. Identifying vulnerable species, and use of fishing effort distribution data of high resolution, may be a more fruitful approach.

Ronnback, P. (1999). "The Ecological Basis for Economic Value of Seafood Production Supported by Mangrove Ecosystems." *Ecological Economics* 29: 235-252.

Rooker, J. R., G. J. Holt and S. A. Holt (1998). "Vulnerability of newly settled red drum (*Scianops ocellatus*) to predatory fish: Is early-life survival enhanced by seagrass meadows?" *Marine Biology* 131: 145-51.

Rose, C., A. Carr, D. Ferro, R. Fonteyne and P. MacMullen (2000). "Using gear technology to understand and reduce unintended effects of fishing on the seabed and associated communities: Background and potential directions." In ICES Working Group on Fishing Technology and Fish Behaviour report, ICES CM 2000/B:03: 25 p.

Summary: This paper addresses the components of various demersal fishing gears that have the greatest impact on benthic habitat, and discusses under what conditions the gear components effects are most pronounced. Several gear types are categorized and their effects summarized. Additionally, methods to study such effects are listed. Implications are made for cooperative research between fishing gear technologists and researchers of benthic effects, to improve gear component designs that could reduce effects on habitat.

Rothschild, B. J., J. S. Ault, P. Gouilletquer and M. He'ral (1994). "Decline of the Chesapeake Bay oyster population: a century of habitat destruction and overfishing." *Marine Ecology Progress Series* 111: 29-39.

The oyster *Crassostrea virginica* population in the Maryland portion of Chesapeake Bay, USA, has declined by more than 50-fold since the early part of this century. The paper presents evidence that the mechanical destruction of

habitat and stock overfishing have been important factors in the decline, even though it is commonly thought that 'water quality' and, more recently, oyster diseases are critical. Quantitative analysis show that the long-term decline of oysters largely results from habitat loss associated with intensive fishing pressure early in this century, and stock overfishing from early in the century through recent times. Furthermore, the major ecological effects on Chesapeake Bay occurred well before World War II, before industrialization and the reported prevalence of disease. To effect the recovery of the ailing Chesapeake Bay oyster stock, a 4-point management strategy is proposed.

Rubec, P. J., J. C. W. Bexley, H. Norris, M. S. Coyne, M. E. Monaco, S. J. Smith and J. S. Ault (1999). "Suitability Modeling to Delineate Habitat Essential to Sustainable Fisheries." *American Fisheries Society Symposium* 22: 108-133.

Rudd, M., M. Tupper, H. Folmer and G. van Kooten (2003). "Policy analysis for tropical marine reserves: challenges and directions." *FISH AND FISHERIES* v.4(no.1): p.65-85.

Marine reserves are considered to be a central tool for marine ecosystem-based management in tropical inshore fisheries. The arguments supporting marine reserves are often based on both the nonmarket values of ecological amenities marine reserves provide and the pragmatic cost-saving advantages relating to reserve monitoring and enforcement. Marine reserves are, however, only one of a suite of possible policy options that might be used to achieve conservation and fisheries management objectives, and have rarely been the focus of rigorous policy analyses that consider a full range of economic costs and benefits, including the transaction costs of management. If credible analyses are not undertaken, there is a danger that current enthusiasm for marine reserves may wane as economic performance fails to meet presumed potential. Fully accounting for the value of ecological services flowing from marine reserves requires consideration of increased size and abundance of focal species within reserve boundaries, emigration of target species from reserves to adjacent fishing grounds, changes in ecological resilience, and behavioural responses of fishers to spatially explicit closures. Expanding policy assessments beyond standard cost-benefit analysis (CBA) also requires considering the impact of social capital on the costs of managing fisheries. In the short term, the amount of social capital that communities possess and the capacity of the state to support the rights of individuals and communities will affect the relative efficiency of marine reserves. Reserves may be the most efficient policy option when both community and state capacity is high, but may not be when one and/or the other is weak. In the longer term, the level of social capital that a society possesses and the level of uncertainty in ecological and social systems will also impact the appropriate level of devolution or decentralization of fisheries governance. Determining the proper balance of the state and the community in tropical fisheries governance will require broad comparative studies of marine reserves and alternative policy tools.

Ruitenbeck, H. J. (1988). Social cost-benefit analysis of the Korup Project, Cameroon. London, WWF for Nature Publication.

Rumohr, H. and T. Kujawski (2000). "The impact of trawl fishery on the epifauna of the southern North Sea." *ICES Journal of Marine Science* 57(5): 1389-1394.

Qualitative historical benthos data (1902-1912) were compared with recent data (1986) to find long-term trends in epifauna species composition in the southern North Sea that may be attributed to fishery-induced changes. In general, the frequency of occurrence of bivalve species declined, whereas scavenger and predator species (crustaceans, gastropods, and sea stars) were observed more frequently in 1986. We suggest that these shifts can be attributed not only to the physical fishery impact, but also to the additional potential food for scavenging and predator species provided by the large amounts of discards and moribund benthos. Our findings are put into the perspective of the general development of the demersal fishery in the southern North Sea. Despite the problems with the historical data set, the comparison presented may be the best illustration achievable of the changes in the benthos from a near-pristine situation to the present conditions after long-term disturbance.

Rumohr, H., H. Schomann and T. Kujawski (1994). Environmental impact of bottom gears on benthic fauna in the German Bight. Environmental impact of bottom gear on benthic fauna in relation to natural resources management and protection of the North Sea. NIOZ Rapport 1994-11. S. J. a. L. Pages 75-86 in de Groot, H.J. (eds.). Texel, The Netherlands.

This subproject concentrated on the investigation of direct effects of beam trawling on benthic fauna (including fishes). This was investigated using imaging methods (video, photo and REMOTS sediment profile photography), and with dredges directly attached to those parts of the gear that might cause damage to benthic animals (shoe, tickler chains). Reference values were obtained by a dredge attached to the beam. The dredge samples clearly revealed the effects of the beam trawl in some bigger taxa such as brittle stars, starfish, larger crustaceans and polychaetes (*Aphrodite aculeata*) although the sediment texture seemed to play an important role in this context. The "chain"-dredges contained more species than the "beam"-dredges, which is further proof of the effects of the tickler chains. The mean number of fishes was double in the chain dredges, and the species number was 1.5 times higher than in the reference sample. Video records displayed a relatively undisturbed reference area 10 sm SE. REMOTS photographs revealed a disturbed surface layer in the IMPACT-box that showed no signs of layering or bioturbative action. Layers with mollusc damaged compared with intact ones in the control area. The epifauna was reduced in abundance. No inner structures (feeding burrows, living chambers, tubes) were visible in the impacted area. At the control site a rich *Ophiura* community and *Lanice* as well as burrowed *Aphrodite* could be observed both in the video and in

the sediment profiles. Close-up video inspections of a 10 m shrimp trawl in the German Wadden Sea showed the relatively low impact of this gear on the sediment and the behaviour of the shrimps in front of the trawl. Sea moss (*Sertularia*) and *Lanice* meadows remained relatively undisturbed after the passage of type of gear.

Sainsbury, K. J. (1987). Assessment and management of the demersal fishery on the continental shelf of northwestern Australia. Tropical snappers and groupers--biology and fisheries management. J. J. Polovina and S. Ralston. Boulder, Colorado., Westview Press: 465-503.

The diverse fish community on the continental shelf of northwestern Australia has been exploited since 1959. The history of exploitation is summarized, and concurrent changes in fish community are inferred from data collected during research surveys. Assessments of the North West Shelf fishery have utilized surplus production models of the Beverton and Holt type. These assessments are described, and their limitations discussed.

Sainsbury, K. J. (1988). The ecological basis of multispecies fisheries and management of a demersal fishery in tropical Australia. I. Fish, P. D. T. I. for and e. J. G. Management. New York, Wiley: 349-82.

Sainsbury, K. J., R. A. Campbell and A. W. Whitelaw (1993). Effects of trawling on the marine habitat on the north west shelf of Australia and implications for sustainable fisheries management. Sustainable Fisheries through Sustainable Fish Habitat. Canberra, Australia, Bureau of Resource Sciences Publication. Australian Government Publishing Service.: 137-145.

The focus of this paper is on the effects of trawling on the marine habitat and the relationship of this habitat and the fish composition on the North West Shelf (NWS) of Australia. This paper is discussed in three parts. First, it addresses some of the problems facing managers of Australia's tropical marine fish resources. Second, the NWS fishery is reviewed and the ecological communities in that region are described. Finally, it describes both the research and management approaches taken in this region. From the results of this study, it was found that the relative composition of the multispecies fish community on the NWS is habitat dependant, and the historical changes in animal composition are partly a result of long-term habitat disturbance due to demersal trawling gear. It is anticipated that continued habitat alteration will further alter species composition. Areas that had been closed to trawling showed that large epibenthic species were slow to recover. The authors also suggest that "adaptive" management strategies have considerable scope in providing information which will guide the decision of long-term management actions.

Saitoh, K. (1998). "Genetic variation and local differentiation in the Pacific cod *Gadus macrocephalus* around Japan revealed by mtDNA and RAPD markers." *Fisheries Science* (Tokyo) v.64(no.5): p.673-679.

This study deals with local differentiation in Pacific cod among three Japanese coastal areas around putative reproductive sites and the western Bering Sea. Restriction and SSCP analyses conducted on the mitochondrial control region showed genetic divergence between some Japanese coastal areas and the Bering Sea. RAPD analysis also indicated divergence between Japanese coastal areas and the Bering Sea. mtDNA analysis revealed low variability and no local distinction among Japanese localities. Calculating gene frequency data sets by two different ways, RAPD markers showed accordance between genetic and geographic distances in Japanese coastal areas.

Sánchez, J. A. and S. D. Cairns (2004). "An unusual new gorgonian coral (Anthozoa: Octocorallia) from the Aleutian Islands, Alaska." *Zool. Med. Leiden* 78.

Despite the abundance and ecological importance of octocorals in Alaskan waters, most of the species in this assemblage remain unidentified and/or undescribed. One of the largest and most abundant species from the Aleutian Islands found at depths ranging between 125 and 512 m is a new and very unusual gorgonian coral. It has stout upright colonies that are laterally branched, with thick, more or less clavate terminal branches. Its major distinguishing characteristic is its possession of tiny sclerites with stubby double heads, which occur in the outermost coenenchyme. Another significant character is its oval capstans with elaborate ornamentation. The gorgonian is described as *Alaskagorgia aleutiana* new genus and species (Cnidaria: Octocorallia: Holaxonia: Plexauridae). It is described and assigned to Plexauridae because of the affinity of DNA sequences (1337 bp mtDNA: ND2 and MSH1) of *A. aleutiana* with other plexaurid corals, even though the predominant coenenchymal sclerites are somewhat smaller and different than is usual in plexaurid genera.

Sathirathai, S. and E. B. Barbier (2001). "Valuing Mangrove Conservation in Southern Thailand." *Contemporary Economic Policy* 19(2): 109-122.

Savino, J. and R. Stein (1982). "Predator-prey interaction between largemouth bass and bluegills as influenced by simulated, submersed vegetation." *Trans Am Fish Soc* 111: 255-266.

Data from the literature suggest that predatory success declines as habitat complexity increases. To explain this phenomenon were studied the predator-prey interaction between largemouth bass *Micropterus salmoides* and bluegills *Lepomis macrochirus* in four laboratory pools (2.4-3.0 m diameter, 0.7 m deep),

each with a different density (0, 50, 250, 1,000 stems/m super(2)) of artificial plant stems. Behavior was quantified for both predator and prey during largemouth bass feeding bouts lasting 60 minutes. Predation success (number of captures) by largemouth bass was similar at 0 and 50 stems/m super(2), then declined to near zero at 250 and 1,000 stems/m super(2). As stem density increased, predator activity declined due to a decrease in behaviors associated with visual contact with prey. Reduced predation success by largemouth bass in habitats of increased complexity apparently is related to increases in visual barriers provided by plant stems as well as to adaptive changes in bluegill behavior.

Scott, D. B. and M. J. Risk (2003). End moraines on the upper Scotian slope: relationship to deep-sea coral and fish habitats. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Smith, M. D. and J. E. Wilen (2003). "Economic impacts of marine reserves: the importance of spatial behavior." JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT 46(2): 183-206.

Marine biologists have shown virtually unqualified support for managing fisheries with marine reserves, signifying a new resource management paradigm that recognizes the importance of spatial processes in exploited systems. Most modeling of reserves employs simplifying assumptions about the behavior of fishermen in response to spatial closures. We show that a realistic depiction of fishermen behavior dramatically alters the conclusions about reserves. We develop, estimate, and calibrate an integrated bioeconomic model of the sea urchin fishery in northern California and use it to simulate reserve policies. Our behavioral model shows how economic incentives determine both participation and location choices of fishermen. We compare simulations with behavioral response to biological modeling that presumes that effort is spatially uniform and unresponsive to economic incentives. We demonstrate that optimistic conclusions about reserves may be an artifact of simplifying assumptions that ignore economic behavior.

Snelgrove, P., T. Blackburn, P. Hutchings, D. Alongi, J. Grassle, H. Hummel, G. King, I. Koike, P. Lambshead, N. Ramsing and V. SolisWeiss (1997). "The importance of marine sediment biodiversity in ecosystem processes." AMBIO v.26(no.8): p.578-583.

Sedimentary habitats cover most of the ocean bottom and therefore constitute the largest. single ecosystem on earth in spatial coverage, Although only a small fraction of the micro-, meio- and macroscopic benthic organisms that reside in and on sediments have been described and few estimates of total species numbers and biogeographic pattern have been attempted, there is sufficient information on a few species to suggest that sedimentary organisms significantly impact major ecological processes. Benthic organisms contribute to regulation of carbon,

nitrogen, and sulfur cycling, water column processes, pollutant distribution and fate, secondary production, and transport, and stability of sediments. Linkages between groups of organisms and the level of functional redundancy is poorly known, however, there is probably substantial redundancy within groups. There is little evidence that biodiversity per se is necessary for benthic systems to contribute to ecosystem services. but because linkages are so poorly known and predictive knowledge confined to a few species, it is not presently possible to predict exactly how species loss will impact these services and ecosystem health. Thus, a precautionary approach of "assume the worst" is advised, and every effort should be made to curtail the species and genetic diversity loss resulting from fishing, pollution, habitat destruction, introduction of non-native (exotic) species, and global warming. Concurrently, scientists must take advantage of exciting, rapidly evolving technology and a rejuvenated interest in biodiversity to provide more concrete and thorough information on benthos and ecosystem processes.

Soh, S. G., Donald R.; Ito, Daniel H. (2001). "The potential role of marine reserves in the management of shortraker rockfish (*Sebastes borealis*) and rougheye rockfish (*S. aleutianus*) in the Gulf of Alaska." *Fishery Bulletin* (Seattle) v.99(no.1): p.168-179.

Shortraker and rougheye rockfish (*Sebastes borealis* and *S. aleutianus*) have been an independent management subgroup of the Gulf of Alaska slope rockfish assemblage since 1991. Special concerns are proposed for the management of these species because they are very slow growing, long-lived, and commercially important. Marine reserves (harvest refugia) have often been proposed as a valuable management tool for mitigating overfishing and maintaining species and habitat diversity. Their effectiveness in fisheries management, however, is poorly understood and concepts regarding their use are largely untested. Our study investigated the potential role of harvest refugia in the management of these two species by using a Geographic Information System (GIS) application to design harvest refugia networks of varying spatial extent. Twenty-year projections employing a population dynamics model were used to compare ending biomass and fishing mortality under the current management system with biomass and fishing mortality under refuge management systems. The results indicate that harvest refugia can be used to greatly reduce discards and serial overfishing of substocks without reducing current catch levels.

Stein, D. L., B. N. Tissot, M. A. Hixon and W. Barss (1992). "Fish-habitat associations on a deep reef at the edge of the Oregon continental shelf." *U S National Marine Fisheries Service Fishery Bulletin* v.90(no.3).

Heceta Bank is a large reef on the edge of the central Oregon continental shelf that supports a wide variety of commercial fisheries. Using the research submersible Delta, we studied fish abundances on Heceta Bank and the relationship between species composition of fish assemblages and bottom types. Cluster analysis indicated that fish assemblages were most unique on mud, boulder, rock ridge, mud and cobble, and mud and boulder substrates. Rockfishes,

particularly pygmy *Sebastes wilsoni*, sharpchin *S. zacentrus*, rosethorn *S. helvomaculatus*, and yellowtail *S. flavidus*, were the most abundant fishes and dominated all substrates except mud, where Dover sole *Microstomus pacificus* and zoarcids *Lycodes pacificus* were most abundant. Principal component analysis (PCA) and canonical correlation analysis (CCA) were used to determine the sources of variation within the data. PCA demonstrated that habitat variability was a fundamental cause of heterogeneity among fish assemblages. In contrast, CCA showed how species occurrences were related to specific substrates. Ontogenetic shifts in behavior and substrate preference occurred in pygmy rockfish. Small juveniles often formed dense schools above the bank's shallower rocky ridges. Larger individuals occurred in nonpolarized assemblages on the bottom in cobble and boulder fields.

Stevens, B. G. (2003). "Settlement, substratum preference, and survival of red king crab *Paralithodes camtschaticus* (Tilesius, 1815) glaucothoe on natural substrata in the laboratory." *Journal of Experimental Marine Biology and Ecology* v.283(no.1-2): p.63-78.

Preferences of red king crab (RKC) *Paralithodes camtschaticus* glaucothoes for a variety of live substrata were tested in the laboratory. Recently molted glaucothoes settled immediately on all substrata except a bare control tank. Preferred substrata (in decreasing order) were hydroids, algae, other (airstones, tank bottom), sand and worms, and did not change much until after molting to stage C1 at day 30. Survival to stage C1 was highest (93%) in the control tank, least (18%) on sand and intermediate (53-60%) on other substrata. Red king crab glaucothoes demonstrate similar preferences for structurally complex biological substrata in the laboratory as they do in the wild. Settlement on sand occurs only as a last resort and results in higher mortality. These results indicate the importance to settling larvae of biogenic oases that may be easily disturbed by hard-on-bottom fishing activities, and underscore the importance of conserving such habitats. Furthermore, knowledge of settlement, habitat selection and substratum preference are essential prior to considering the potential of king crabs for stock enhancement or aquaculture.

Stevens, B. G. and K. Swiney (2003). "Settlement, survival, and predation of red king crabs on natural and artificial substrata." *Journal of Shellfish Research* v.22(no.1): p.356.

Stone, R. (2004). Depth distribution, fisheries interactions, and habitat of deep-sea corals in the Aleutian Islands of Alaska-Preliminary research data presented at the American Association for the Advancement of Science. Seattle, Washington, NOAA Fisheries, Alaska Fisheries Science Center, Auke Bay Laboratory.

Summaries of archived survey data and recently acquired fisheries bycatch specimens indicated that the Aleutian Islands in Alaska may harbor the highest abundance and diversity

of cold-water corals in the world. To verify these observations, the first ever research submersible surveys were launched in the central Aleutian Islands in 2002 to examine coral habitat, associated communities, and interactions with the diverse and important fisheries there. Submersible observations confirmed that corals, especially gorgonians and hydrocorals, were widely distributed in that region; corals were found at 30 of 31 dive sites investigated. Percent coverage of corals ranged from approximately 5 percent on low-relief pebble substrate to 100 percent coverage on high-relief bedrock and boulder outcrops. Unique coral habitat consisting of high density "gardens" of corals, sponges, and other sedentary invertebrates was found at 3 sites between 150 and 350 m depth. "Gardens" were similar in structural complexity to tropical coral reefs with which they shared several important characteristics including a rigid framework, complex vertical relief, and high taxonomic diversity. This habitat had not been previously documented in the North Pacific Ocean or Bering Sea and appeared to be particularly sensitive to bottom disturbance. Gorgonians and hydrocorals ranged from the shallow subtidal zone to depths greater than 350 m but were most common between 100 and 300 m. This is the same depth range where most of the area's fishing effort is distributed and approximately 5 percent of the corals enumerated from video footage to date have been damaged or detached from the seafloor. These data indicate that incidental mortality of deep-sea corals will be a challenging problem in the areas fisheries that use bottom contact.

Stone, R. P. and P. W. Malecha (2003). Deep-sea coral habitat in the Aleutian Islands of Alaska. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Sulak, K. J., S. W. Ross and M. S. Nizinski (2003). Ichthyofauna of deep sea coral banks on the continental slope off the southeastern United States. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

Swallow, S. K. (1990). "Depletion of the environmental basis for renewable resources: The economics of interdependent renewable and nonrenewable resources." *Journal of Environmental Economics and Management* 19: 281-296.

This paper synthesizes familiar theories of nonrenewable and renewable resource economics in a two-sector, partial-equilibrium analysis of efficient trade-offs between renewable resource production and environmental development. The irreversible impacts of coastal zone development provide a motivating example. While development proceeds, the efficient harvest of renewable resources may exceed the "sustainable" rate. While development may involve several periods of growth and decline, once development begins it proceeds without significant interruptions. If a profitable renewable resource sector survives, development

ceases before exhausting all profitable opportunities. Interdependent stocks reduce distinctions between resource types because each sector exhibits features of the other.

Therrien, J., I. Frenette, A. St.-Hilaire, E. Ferguson, S. Bastien-Daigle and C. Godin (2000). "Preliminary index of essential habitats for certain marine species of importance in the eastern region of New Brunswick." Canadian Manuscript Report of Fisheries and Aquatic Sciences(no.2514): p.i-vi; 1-206.

This document is a useful planning tool for management and conservation needs, whether from the perspective of the Oceans Act or of related objectives such as habitat protection, integrated fisheries management plan preparation or ecosystemic management of resources. With the help of many stakeholders (fishers, fishery officers and biologists), a representative portrait of the information currently available on major marine resources in Eastern New Brunswick was developed. The information is presented in the form of essential habitats for certain marine species, with a total of 30 habitats for 31 species or groups of species having been identified. They are divided in three ecozones: Chaleur Bay, Shediac Valley and the Northumberland Strait. The term essential habitat is used to characterize each species-habitat grouping representative of a vital habitat for a particular wildlife species. These areas are essential for various crucial stages in the life cycle of the species (spawning ground, rearing area, feeding ground, migration area, etc.), or they constitute a major area of concentration, particularly for mostly sedentary species, such as molluscs, for which the boundaries of the area would remain relatively constant from one year to another. Fish concentration areas are generally not included, with the exception of those associated with one particular life stage (larva or juvenile) or a threatened species (cod).

Thrush, S. and P. K. Dayton (2002). "Disturbance to marine benthic habitats by trawling and dredging: Implications for marine biodiversity." Annual Review of Ecology and Systematics v.33: p.449-473.

The direct effects of marine habitat disturbance by commercial fishing have been well documented. However, the potential ramifications to the ecological function of seafloor communities and ecosystems have yet to be considered. Soft sediment

organisms create much of their habitat's structure and also have crucial roles in many population, community, and ecosystem processes. Many of these roles are filled by species that are sensitive to habitat disturbance. Functional extinction refers to the situation in which species become so rare that they do not fulfill the ecosystem roles that have evolved in the system. This loss to the ecosystem occurs when there are restrictions in the size, density, and distribution of organisms that threaten the biodiversity,

resilience, or provision of ecosystem services. Once the functionally important components of an ecosystem are missing, it is extremely difficult to identify and

understand

ecological thresholds. The extent and intensity of human disturbance to oceanic ecosystems is a significant threat to both structural and functional biodiversity and in many cases this has virtually eliminated natural systems that might serve as baselines to evaluate these impacts.

Thrush, S. F., J. E. Hewitt, V. J. Cummings and P. K. Dayton (1995). "The impact of habitat disturbance by scallop dredging on marine benthic communities -what can be predicted from the results of experiments." *Marine Ecology Progress Series* 129(1-3): 141-150.

Field experiments were conducted on 2 subtidal sandflats to identify the short-term impacts of commercial scallop dredging on macrobenthic communities. The 2 sites (1400 m²) were situated 14 km apart, both at about 24 m depth, with similar exposure aspects and were characterised by infaunal communities dominated by small and short-lived species. Prior to dredging, preliminary sampling failed to reveal significant differences in the density of common macrofauna within each site, although community composition was distinctly different between sites. The experiment was initiated by using a commercial scallop dredge to dredge half of each study site. Macrofauna samples were collected in both the dredged and adjacent reference plot at each site immediately after dredging and again 3 mo later. The density of common macrofaunal populations at each site decreased as a result of dredging, with some populations still significantly different from the adjacent reference plot after 3 mo. Significant compositional differences in the assemblage structure between dredged and reference plots were also recorded at each site over the course of the experiment. The findings of this experiment are considered a conservative assessment of bottom disturbance by fishing because of the area of seabed used, the types of community present and the intensity of disturbance used in the experiment. The findings of this and similar short-term experiments are discussed in light of the need to predict and assess possible large-scale changes to benthic communities as a result of habitat disturbance by fishing.

Thrush, S. F., J. E. Hewitt, G. A. Funnell, V. J. Cummings, J. Ellis, D. Schultz, D. Talley and A. Norkko (2001). "Fishing disturbance and marine biodiversity: the role of habitat structure in simple soft-sediment systems." *Marine Ecology Progress Series* 223: 277-286.

Broad-scale anthropogenic disturbances that reduce the density of epifauna and homogenise surficial sediments can have important consequences for seafloor biodiversity. We investigated the habitat structure and macrofaunal diversity of relatively simple soft-sediment habitats over a number of spatial scales (cm to km) to identify the role of habitat structure in influencing macrobenthic diversity and to assess the validity of using habitat structure in influencing macrobenthic diversity and to assess the validity of using habitat structure as a surrogate measure for biodiversity. We sampled 10 locations with differences in habitat

structure using a sampling design that nested macrobenthic core samples within videoed transects of the floor. This allowed us to determine relationships between observable habitat structure and macrobenthic diversity at a number of spatial scales. We characterised elements of habitat structure based on direct counts of surficial sediment characteristics and the presence of other immobile features, many of which were biogenic in origin. We also used multivariate measures (the relative multivariate dispersion, the mean and range of the Bray-Curtis dissimilarity along the transects) to characterise habitat structure at the transect scale. We developed regression models based on measures of habitat structure that explained 74 to 86% of the variance in macrobenthic diversity. This result suggests that removal of habitat structure in relatively low-structure soft-sediment systems will significantly decrease their biodiversity, and consequently that of the wider marine ecosystem.

TILMAN, D., R. MAY, C. LEHMAN and M. NOWAK (1994). "HABITAT DESTRUCTION AND THE EXTINCTION DEBT." *NATURE* 371(6492): 65-66.

HABITAT destruction is the major cause of species extinctions(1-3) Dominant species often are considered to be free of this threat because they are abundant in the undisturbed fragments that remain after destruction. Here we describe a model that explains multispecies coexistence in patchy habitats(4) and which predicts that their abundance may be fleeting. Even moderate habitat destruction is predicted to cause time-delayed but deterministic extinction of the dominant competitor in remnant patches. Further species are predicted to become extinct, in order from the best to the poorest competitors, as habitat destruction increases. Moreover, the more fragmented a habitat already is, the greater is the number of extinctions caused by added destruction. Because such extinctions occur generations after fragmentation, they represent a debt-a future ecological cost of current habitat destruction.

Tupper, M. and R. G. Boutilier (1995). "Effects of habitat on settlement, growth, and postsettlement survival of Atlantic cod (*Gadus morhua*).*" Canadian Journal of Fisheries and Aquatic Sciences* v.52(no.9): p.1834-1841.

Settlement and growth of age 0+ cod were monitored using snorkel and self-contained underwater breathing apparatus (SCUBA) in four distinct habitat types (sand, seagrass, cobble, and rock reef) in St. Margaret's Bay, Nova Scotia. Newly settled cod were marked with acrylic dye, allowing repeated visual length estimates of individual fish. Settlement of cod did not differ between habitat types, but postsettlement survival and subsequent juvenile densities were higher in more structurally complex habitats. These differences appear to be due to increased shelter availability and decreased predator efficiency in structurally complex habitats. Growth rate was highest in seagrass beds, while the efficiency of cod predators was lowest and cod survival was highest on rocky reefs and cobble bottoms. Thus, trade-offs occur between energy gain and predation risk. In St. Margaret's Bay, the population structure of Atlantic cod may be less

influenced by patterns of larval supply than by postsettlement processes such as habitat-specific growth and mortality.

Turner, S. J., S. F. Thrush, J. E. Hewitt, V. J. Cummings and G. Funnell (1999). "Fishing impacts and the degradation or loss of habitat structure." *Fisheries Management and Ecology* v.6(no.5): p.401-420.

The wider effects of fishing on marine ecosystems have become the focus of growing concern among scientists, fisheries managers and the fishing industry. The present review examines the role of habitat structure and habitat heterogeneity in marine ecosystems, and the effects of fishing (i.e. trawling and dredging) on these two components of habitat complexity. Three examples from New Zealand and Australia are considered, where available evidence suggests that fishing has been associated with the degradation or loss of habitat structure through the removal of large epibenthic organisms, with concomitant effects on fish species which occupy these habitats. With ever-increasing demands on fish-stocks and the need for sustainable use of fisheries resources, new approaches to fisheries management are needed. Fisheries management needs to address the sustainability of fish-stocks while minimizing the direct and indirect impacts of fishing on other components of the ecosystem. Two long-term management tools for mitigating degradation or loss of habitat structure while maintaining healthy sustainable fisheries which are increasingly considered by fisheries scientists and managers are: (1) protective habitat management, which involves the designation of protected marine and coastal areas which are afforded some level of protection from fishing; and (2) habitat restoration, whereby important habitat and ecological functions are restored following the loss of habitat and/or resources. Nevertheless, the protection of marine and coastal areas, and habitat restoration should not be seen as solutions replacing conventional management approaches, but need to be components of an integrated programme of coastal zone and fisheries management. A number of recent international fisheries agreements have specifically identified the need to provide for habitat protection and restoration to ensure long-term sustainability of fisheries. The protection and restoration of habitat are also common components of fisheries management programs under national fisheries law and policy.

van Santbrink, J. W. and M. J. N. Bergman (1994). Direct effects of beam trawling on macrofauna in a soft bottom area in the southern North Sea. Environmental impact of bottom gear on benthic fauna in relation to natural resources management and protection of the North Sea. NIOZ Rapport 1994-11. S. J. a. L. Pages 147-178 in de Groot, H.J. (eds.). Texel, The Netherlands.

Direct effects of trawling with commercial 12-m beam trawls on the abundance of benthic species in a soft bottom area in the southern North Sea were studied by comparing densities before and after trawling. Various sampling gears were used, including a benthos dredge (Triple-D) developed especially for this study. After trawling a study area twice, mortality could be estimated for a number of species.

For fish species, mortality varied from 4% (small fish) to 75% (larger fish) of the numbers initially present. Mortality exceeded 100% for dab, *Limanda limanda*, as it rapidly immigrates into the trawled area already during trawling. For invertebrate species, mortality was variable as well, and estimated at 3-19% for echinoderms, 0-85% for molluscs, 4-74% for crustaceans, <1-56% for annelids, and 70% for anthozoans. Dab was a predominant scavenger on damaged or exposed fauna on the recently trawled seabed. The presence of infauna species in catches of the 12-m beam trawls indicated, that the sediment was disturbed by the tickler chains to a depth of approximately 2 to 4 cm.

Vassilopoulou, V. and C. Papaconstantinou (2000). "Comparative study of fish assemblages in trawl reserves and adjacent areas." 6th Hellenic Symposium on Oceanography and Fisheries. Chios, Greece, May 23-26, 2000. Proceedings. Volume 2. Fisheries, Inland waters, Aquaculture. 6o Panellinio Symposio Okeanografias kai Alieias. Chios, 23-26 Maiou 2000. Praktika. Tomos 2. Alieia, Esoterika ydata, Ydatokalliergeies, NCMR Association of Employees, [Athens (Greece)], Proceedings of the Hellenic Symposium on Oceanography and Fisheries. 2: 192-194.

Data are provided on total biomass estimates, diversity of the demersal fish assemblages and body size distribution of certain so-called 'target species' for the trawl fishery in six neighboring regions of the Aegean Sea (Greece), three normally trawled and three closed to the trawlers, in order to investigate the existence of possible differences, that could be related to trawling activities. Total biomass was higher in the untrawled areas in relation to the trawled ones. Diversity indices did not exhibit any particular trend, underlining the effect of habitat type on fish assemblages. Larger specimens of the target species appeared in the untrawled areas. Further research is needed in order to increase information and clarify certain aspects associated with trawl reserves.

Veale, L. O., A. S. Hill, S. J. Hawkins and A. R. Brand (2000). "Effects of long-term physical disturbance by commercial scallop fishing on subtidal epifaunal assemblages and habitats." *Marine Biology* 137(2): 325-337.

This paper examines spatial differences in the distribution of by-catch assemblages from the scallop [*Pecten maximus* and *Aequipecten opercularis*] fishing grounds in the North Irish Sea, during 1995. The sites examined have been exposed to differing known levels of fishing disturbance by scallop dredging, based on unusually high-resolution data extracted from fishermen's logbooks. Uni- and multivariate

techniques have been used on a production dataset (a value which incorporates both abundance and biomass figures), as well as abundance and biomass data individually. The original species list was reduced to higher taxonomic groupings in line with the theory that the latter is more appropriate for detecting anthropogenic change. Species diversity and richness, total number of species, and total number of individuals all decrease significantly with increasing fishing effort. Species dominance increases with effort. Total abundance, biomass and

production, and the production of most of the major individual taxa investigated decrease significantly with increasing effort. Multivariate analysis reveals a significant relationship between fishing effort and by-catch assemblage structure. The taxa most responsible for the differences are the echinoids and cnidarians, but prosobranch molluscs and crustaceans also contribute to the differences. Bycatch assemblage structure is more closely related to fishing effort than any other environmental parameter investigated, including depth and sediment type. We observed an approximately linear decrease in diversity with increasing fishing disturbance, and suggest this is primarily due to selective removal of sensitive species and, more importantly, habitat homogenisation. These results were interpreted in the light of ecological theories relating disturbance to community structure. The argument that invertebrate scavenger populations benefit from prolonged exposure to fishing disturbance was also examined, but no supporting evidence was found.

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Walters, C. J. (1986). *Adaptive management of renewable resources*. New York, NY, MacMillan.

Warner, R. R. S., Stephen E.; Caselle, Jennifer E. (2000). "Larval accumulation and retention: Implications for the design of marine reserves and essential fish habitat." *Bulletin of Marine Science* v.66(no.3): p.821-830.

For many marine fishes, the literature contains indications of a surprising amount of local larval retention, even in species with long pelagic larval durations. In addition, there is circumstantial evidence that, before settlement, larvae accumulate in offshore areas. Proper design of marine reserves should include consideration of larval accumulation and retention. If retention and accumulation turn out to be common features of local marine population dynamics, areas important to these processes must be included in reserves and in the designation of essential fish habitat. If recruitment limitation is a common feature of the dynamics of local marine populations, it follows that maintenance of the supply of potential settlers is critical. Extensive larval retention may require major reassessment of fishery-enhancement models of marine reserves that depend on larval export for their effects.

Watling, L. and E. A. Norse (1998). "Disturbance of the seabed by mobile fishing gear: A comparison to forest clearcutting." *Conservation Biology* v.12(no.6): 1180-1197.

Bottom trawling and use of other mobile fishing gear have effects on the seabed that resemble forest clearcutting, a terrestrial disturbance recognized as a major threat to biological diversity and economic sustainability. Structures in marine benthic communities are generally much smaller than those in forests, but structural complexity is no less important to their biodiversity. Use of mobile fishing gear crushes, buries, and exposes marine animals and structures on and in

the substratum, sharply reducing structural diversity. Its severity is roughly comparable to other natural and anthropogenic marine disturbances. It also alters biogeochemical cycles, perhaps even globally. Recovery after disturbance is often slow because recruitment is patchy and growth to maturity takes years, decades, or more for some structure-forming species. Trawling and dredging are especially problematic where the return interval -the time from one dredging or trawling event to the next -is shorter than the time it takes for the ecosystem to recover; extensive areas can be trawled 100-700% per year or more. The effects of mobile fishing gear on biodiversity are most severe where natural disturbance is least prevalent, particularly on the outer continental shelf and slope, where storm-wave damage is negligible and biological processes, including growth, tend to be slow. Recent advances in fishing technology (e.g., rockhopper gear, global positioning systems, fish finders) have all but eliminated what were de facto refuges from trawling. The frequency of trawling (in percentage of the continental shelf trawled per year) is orders of magnitude higher than other severe seabed disturbances, annually covering an area equivalent to perhaps half of the world's continental shelf, or 150 times the land area that is clearcut yearly. Mobile fishing gear can have large and long-lasting effects on benthic communities, including young stages of commercially important fishes, although some species benefit when structural complexity is reduced. These findings are crucial for implementation of "Essential Fish Habitat" provisions of the U.S. Magnuson-Stevens Fishery Conservation and Management Act which aim to protect nursery and feeding habitat for commercial fishes. Using a precautionary approach to management, modifying fishing methods, and creating refuges free of mobile fishing gear are ways to reduce effects on biological diversity and commercial fish habitat.

Wheeler, A. J., B. J. Bett, D. S. M. Billett, D. G. Masson and A. J. Grehan (2003). The impact of demersal trawling on NE Atlantic coral ecosystems with particular reference to the Northern Rockall Trough. Second International Symposium on Deep Sea Corals, Erlangen, Germany.

White, A. V., HP ; Arin, T (2000). "Philippine coral reefs under threat: The economic losses caused by reef destruction." MARINE POLLUTION BULLETIN v.40(no.7): p.598-605.

In the Philippines, coral reef fisheries provide livelihood for more than a million small-scale fishers who contribute almost US\$ 1 billion annually to the country's economy. The rapidly growing population needs increasing amounts of fish and other marine organisms. However, overfishing, destructive fishing methods and sedimentation have damaged or destroyed many reef areas. Fish catches have fallen well below the sustainable levels of healthy reefs. The economic losses to the coastal fishing population are considerable. Various programmes have and are trying to counter coral reef decline by establishing sustainable management regimes. The economic benefits of such programmes appear to exceed their investment costs. As an example, the start-up and maintenance costs of a

successful island marine reserve project have been compared to the losses caused by reef destruction and the gains from reef management. The results clearly show that the economic benefits from a managed reef area due to higher catches and revenue from small-scale tourism far exceed costs. Coral reefs are also a major attraction for an increasing number of local and international tourists. In addition to providing income for the tourism industry, these reef visitors are often willing to contribute to the costs for reef management. The annual willingness-to-pay assessed in three popular diving destinations are significant. An estimated US\$ 300 000 could be collected annually as entrance fees or donations in Mabini, Batangas alone. It is estimated that the 27 000 km(2) of reef in their degraded condition still contribute at least US\$ 1.35 billion annually to the economy. Reef management involving local fishing communities, local governments and other concerned organizations is a cost-effective way to alleviate the pressure on the numerous threatened coral reefs. In addition, economic valuation and cost-benefit analysis can provide essential information to support more investment in reef conservation.

Yoklavich, M. M., H. G. Greene, G. M. Cailliet, D. E. Sullivan, R. N. Lea and M. S. Love (2000). "Habitat associations of deep-water rockfishes in a submarine canyon: An example of a natural refuge." *Fishery Bulletin* (Washington D C) v.98(no.3): p.625-641.

A multidisciplinary assessment of benthic rockfishes (genus *Sebastes*) and associated habitats in deep water was conducted in Soquel Submarine Canyon, Monterey Bay, California. Rock habitats at depths to 300 m were identified by using bathymetric and side-scan sonar imaging, verified by visual observations from a manned submersible, mapped and quantified. Species composition, abundance, size, and habitat specificity of fishes were determined by using a video camera and parallel laser system along transects made by a submersible. We counted 6208 nonschooling fishes representing at least 52 species from 83 10-min strip transects that covered an estimated 33,754 m². Rockfishes represented 77% of the total number of individuals, and included a minimum of 24 species. Six distinct habitat guilds of fishes were manifest from habitat-based clustering analysis: small species were associated with mud and cobble substrata of low relief, and larger species of rockfishes were associated with high-relief structures such as vertical rock walls, ridges, and boulder fields. There was remarkable concordance between some of the guilds identified in Soquel Canyon and the results of other habitat-specific assessments of fishes along the west coast of the United States from central California to Alaska. These generalities are valuable in predicting community structure and evaluating changes to that structure, as well as in applying small-scale species-habitat relationships to broader-scale fishery resource surveys. Additionally, establishment of these groups is critical when incorporating the concept of essential fish habitat (EFH), and negative impacts to it, into the management of fisheries in relatively deep water, as required by the Sustainable Fisheries Act of 1996. High numbers of large rockfishes (e.g. *Sebastes chlorostictus*, *S. levis*, *S. rosenblatti*, and *S. ruberrimus*) were locally associated with rock ledges, caves, and overhangs at sites having little or no

evidence of fishing activity. Abundance and size of several species were lower at fished than at unfished sites. We suggest that rock outcrops of high relief interspersed with mud in deep water of narrow submarine canyons are less accessible to fishing activities and thereby can provide natural refuge for economically important fishes, as exemplified in Soquel Canyon.

